WORKING PAPER

Automation of work
Literature review

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

Contents

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Introduction

Recent developments in robotics, Artificial Intelligence, and machine learning are linked to a new (or rather revamped) discussion about automation, as the replacement of human input by machine input for some tasks in production becomes more widespread not only in manufacturing (Fernández-Macías, 2017) but also in the service sector. These technologies are enabling machines/robots to perform tasks previously considered to be too difficult for automation. Moreover, artificial intelligence is beginning to engage in activities that before were expected to require human judgement and experience. There are several examples for these advancements, to name just a few: the University of Hertfordshire has developed a humanoid robot called KASPAR that is used as a therapeutic toy for children with autism in order to develop their social interaction skills[1] (Dickerson et al, 2013); robot 'skin' is able to 'feel' textures and is as sensitive as human skin[2] (Núñez et al, 2017); Google's DeepMind and the University of Oxford created a lip reading system[3] which could easily outreach a professional human lip reader: the human lip reader had 12.4% of words error-free, the computer had 46.8% of words without errors (Manyika et al, 2017, p. 26); IBM's Watson[4] is being applied to screen images for cancer indicators (Codella et al, 2016).

The revamped debate on the implications of automation naturally leads to a discussion on the long-term consequences for the economy, the labour market and job quality. There are strikingly different arguments and visions of the future. Whereas many picture a future where robots substitute a high number of workers (blue- and white-collar workers) in a variety of tasks including ones that require cognitive skills, augmenting income inequality, and leading to technological unemployment and breakdowns in the social order, others expect a future in which human creativity will continue to create new jobs and new forms of cooperation between humans and machines (Smith and Anderson, 2014, p. 5).

This literature review takes stock of the implications of automation for the labour market, job quality, social dialogue and social policy emerging from recent studies in the field to explore the main trends and findings and to identify research gaps and inform future research. 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 documents are published on an ongoing basis. The geographic scope is EU Members States with comparison to developments in the United States were applicable. The review includes documents up to August 2017.

For a wider overview of the implications of the digital age for work and employment, see the concept paper on 'Automation, digitisation and platforms. Implications for work and employment' as well as the separate literature reviews on platforms and the digitisation of the production process.

Technology description

The term 'automation of work' refers to tasks previously performed by human labour, which are now produced with capital (Acemoglu and Restrepo, 2016, pp. 2–3), or rather to machines taking over tasks and either reducing time humans spend on carrying them out or entirely performing those tasks (Bessen, 2016, p. 3). For the purpose of this literature review, automation is understood as the replacement of (human) labour input by (digitally-enabled) machine input for some types of tasks within production and distribution processes (Eurofound, 2017). Automation of work refers to any or a combination of the following technologies: advanced robotics, Artificial Intelligence (AI) and machine learning.

[1] See http://www.herts.ac.uk/kaspar

[2] See https://www.forbes.com/sites/hilarybrueck/2017/03/22/solarrobotskin/#55a1a53d3484

[3] See http://www.ox.ac.uk/news/2017-03-17-new-computer-software-programme-excels-lip-reading

[4] See https://www.ibm.com/blogs/research/2016/11/identifying-skin-cancer-computer-vision/

Disambiguation of the terms AI, machine learning and deep learning has been described by several authors and it defines AI as the biggest area of research which explores ways of making machines (computers/robots) to be 'intelligent', that is to act as a human. Machine learning is a sub-area of AI and it is defined as the use of algorithms to learn insights from data. Deep learning is the use of a combination of sophisticated machine learning algorithms which can be used to recognise complicated patterns such as those found in speech and images recognition and which can keep improving their parameters without human further human intervention (Buduma and Locascio, 2017) .

Advanced robotics

Robotics is any kind of mechanical device that can perform tasks and interact without human assistance. Some examples of advanced digital robotics include: soft robotics (non-rigid robots built with soft and deformable materials that can manipulate items of varying size, shape and weight with a single device); swarm robotics (coordinated multi-robot systems which often involve large numbers of mostly robots performing physical tasks); tactile/touch robotics (robotic body parts, for example biologically inspired hands, with capability to sense, touch, exhibit dexterity, and perform a variety of tasks); and humanoid robots (robots physically similar to human beings; they integrate a range of Artificial Intelligence (AI) and robotics technologies and are able to perform a variety of human tasks) (Manyika et al, 2017).

Artificial intelligence

Artificial Intelligence (AI) is a field of computer science focusing on developing systems that have 'intelligence'. It is a science and set of computational technologies, inspired by the human's way of using their bodies and nervous systems to sense, learn, reason, and take action (Stone et al, 2016, p. 4). AI is being used to build smart systems to collaborate effectively with people. Examples of AI applications are: autonomous cars and trucks (wheeled vehicles that are able to operate without a human driver); unmanned aerial vehicles (flying vehicles capable of operating without a human pilot, known as drones); chatbots (AI systems designed to simulate conversation with human users); and robotic process automation (replicating the actions of a human being by interacting with the user interfaces of other software systems).

Machine learning

Machine learning can refer to supervised or unsupervised learning techniques. Supervised learning trains an algorithm to correctly classify a new batch of data; it is used, for example, for spam detection. Unsupervised learning is instead a method that implies the use of algorithms for pattern (rules) discovery without a direct input from the researcher, its used for example for customer purchases analysis (that is, which products are usually bought together) (Hahsler et al, 2005).

The table below summarises the application of technologies described above:

Table 1. Applications of technologies related to automation of work

Advanced robotics	**Artificial intelligence**	**Machine learning**
• Soft robotics • Swarm robotics • Tactile/touch robotics • Humanoid robots	• Autonomous vehicles • Chatbots • Robotics process automation	• Supervised learning • Unsupervised learning

Source: Authors' own elaboration based on Manyika et al (2017).

To put this in context, it is important to point out that applications of these technologies can all be found under the Industry 4.0 concept (discussed in Peruffo et al, 2017): automation together with the digitisation of production processes (3d printing, Internet Of Things and virtual/augmented reality) are changing the way production, its supply chain, and the work around it, is organised.

Scale, scope, and sectors of automation technologies

The Gartner Hype Cycle for emerging technologies[5], a forecasting tool for technological developments, places AI, machine learning and smart robots at the peak of the hype cycle (that is, maximum level of inflated expectations) with predictions of widespread adoption in the industry or in services between 5 and 10 years (cognitive computing). This means that the perceived potential of these technologies is very high but that implementation will actually take longer than the current narrative suggests. Possible causes of the delay between expectation and implementation could be Technology Readiness Levels[6], that is the level of applicability of the technology, and the investment required to acquire these new technologies or products thereof (Eurofound, 2017).

At global level, data from the World Robotics 2016 report (International Federation of Robotics, 2016) show that most industrial robots are present in the automotive industry, which is the sector with the highest density of robots worldwide; other sectors that intensively use robots are electrical and electronics, metal, and chemicals. A European Commission report (2016) discussing the use of industrial robots in manufacturing industries in Europe finds that while almost half of manufacturers of rubber and plastic products and manufacturers of transport equipment already use industrial robots in their production processes, robots are only used by one out of five companies in the textile industry. The countries with the highest number of industrial robots per 10,000 employees in manufacturing (in the sample considered) in 2012 are Germany, Sweden, Italy, Spain and France. This should not be a surprise since all these countries had a strong automotive industry where robots are widely used. The highest percentage of companies using robots in Europe is in Spain, France and Switzerland (note the 'at least one robot'):

> *'47% of Spanish firms, 42% of French firms and 39% of Swiss firms used at least one industrial robot in their factories in 2012 followed by Sweden (35%) and Austria (32%). The lowest rate of industrial robot deployment is reported in the Netherlands (24%)'* (European Commission, 2016, p. 3).

In terms of expected growth in the annual supply of industrial robots in different geographical regions the biggest increase, by 2018, is meant to happen in Asia/Australia[7]. Essentially, automation is more likely to happen in countries where workers enjoy higher wages (EU big 5, US, Japan) and/or in countries with a large population (India, China). For Asia this forecast is in line with the argument that low levels of workers' organisation could favour automation due to a low level of social dialogue interaction while for Western economies the argument of replacement of high wages can be applied.

As far as the services sector is concerned, an example of how positions on automation are diverging between estimates and experts' opinions is the study by Opimas predicting the disappearance of 90,000 jobs in fund management in the next seven years. However, according to sector's experts, even if jobs disappear, there might be new jobs created, so this projection should be taken with caution. As an example, analyst teams are currently composed of approximately 10 analysts, future teams might be formed by seven or eight people, but probably they will include a couple of data scientists who would help analysts to customise algorithms.(Financial Times, 2017). Nevertheless, even if exact forecasts are not available, changes are underway. Newspaper articles reporting facts where content follows a pattern (financial reports, football matches) can now be provided by software invented by the company Narrative Science and its competitors (Carlson, 2015) and the prevision with the

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[5] https://www.gartner.com/newsroom/id/3784363

[6] Definition of Technology readiness level (European Commission).

[7] Perhaps Australia should not have been aggregated with Asia since the top three countries are China, India and Japan.

highest level of automation foresees that in 15 years 90% of the news could be written by automated processes. Administration and logistics are also two sectors where it is likely to see an increase in automation (Arntz, Gregory, & Zierahn, 2016; Manyika et al, 2017); caution should be used when looking at these general trends. Automation probabilities change for each country depending on the particular sets of rules and regulations in place as shown by the analysis conducted by PWC on the difference of automation probabilities between UK and US (PricewaterhouseCoopers, 2017).

Implications for the labour market

The threads of the technological debate of the past, the extent of technological impact on work and employment and solutions for mass unemployment which might result from the widespread adoption of automation of work technologies, have been picked up again in the current debate on automation. Several recent studies examine the effects of technological changes on the labour market. Two main aspects are being discussed: first, the substitutability of human labour by robots and machines, which also involves the discussion of changes in task structures and work activities as well as employment shifts in sectors; second, growing inequalities, involving labour market polarisation and upgrading, and the need for new skills that are required for humans to compete against their potential replacements or to perform jobs which complement those of machines. Where possible, the impact of technology on different demographic groups including gender will be differentiated in the following discussions.

Substitutability of human labour by robots and machines

Studies on the substitutability of human labour by automation technologies show very different results, often depending on the methodological approach they use. This section gives an overview of studies which examined the issue of substitutability of human labour using different approaches and the following section looks at the labour market shifts provoked by automation. First, differences between the two main approaches in the literature, skill biased technological change (STBC) and routine biased technological change (RBTC), are compared. The SBTC hypothesis assumes that computerisation has a skill-biased effect on labour demand: since technological advances can substitute low-skilled rather than high-skilled workers more often and tend to complement the latter, the risk of a job being automated is higher for low-skilled and low-income individuals. This hypothesis implies that technological change has an upgrading effect and tends to expand employment in higher-skilled occupations relative to lower-skilled occupations (Acemoglu, 2002). From a macro perspective it can be seen that there is an upgrading but it might not be necessarily true for individuals who might get caught in the change and not able to upskill in the short run. The RBTC hypothesis (which derives from the earlier SBTC hypothesis) emphasises that it is rather the amount of routine that a job involves than the skills it requires which determines the substitutability of jobs.

A seminal study in this debate is the one by Frey and Osborne (2013). They built on the task model formerly used by Autor et al (2003), but while the earlier model predicted that automation is limited to routine tasks, their model can be extended to any non-routine task that can be seen as an ‘engineering bottleneck’ to automation. Engineering bottlenecks are occupations that involve creative or social intelligence tasks and complex perception and manipulation tasks (Frey and Osborne, 2013, pp. 22–27). A negative relationship between automation of jobs and educational job requirements was also observed in the RBTC approach: automation is lower if jobs require social interaction (that is cooperation with others or influencing others). The finding that automation probability is higher in jobs that involve routine tasks and lower if jobs require social interaction is in line with the task-based literature (Arntz et al, 2016, pp. 12–14). Osborne and Frey (2013) estimated a probability of 47% of total US employment disappearing in the next 20 years (by 2033) by taking into consideration computerisation for 702 occupations arguing that computerisation will not only affect routine task (rule-based and repeatable activities), but also more and more non-routine cognitive and manual tasks. As summarised by Valenduc and Vendramin (2017), Osborne and Frey's methodology has been applied to forecast European substitutability probabilities of jobs[8] (Baert and Ledent, 2015; Bowles, 2014; Deloitte, 2014, 2015; RolandBerger, 2014) finding similar probabilities of automation (30% to 40%).

However, some researchers think that the limitation in Osborne and Frey's approach, recognised by the authors themselves, was to assume that entire occupations would disappear: subsequent studies changed these assumptions by breaking occupations into tasks and thus measuring the probability of task automation and not of entire jobs (Arntz et al, 2016; Bessen, 2016; Bisello and Fernández-Macías, 2016; Manyika et al, 2017). Results, according to the RBTC approach, reported much lower probabilities of automation: OECD (Arntz et al, 2016) estimated that on average 9% of jobs are automatable across OECD member countries. The authors also highlighted heterogeneities across countries: the risk of automation ranges from 6% in Korea to 12% in Austria.

Time horizon of technological change

As remarked by Bowles (2014), the literature can be broadly divided between those whose results forecast changes in the short term (Autor, 2013; McAfee and Brynjolfsson, 2014) due to the acceleration of technological developments and those who argue that changes will take place gradually and jobs will be created in other sectors or the nature of tasks will change. In between these two positions, Bessen (2016) affirms that the substitution effect counterbalances the increase effect, so, a rise in computer use sees a small increase in employment (Bessen, 2016). However, this means that ICT skills must be already available among the workforce in order for this increase to happen. The question to be addressed then becomes about the capability of education and apprenticeship systems to provide this type of skills to the workforce. Along this lines, Manyika et al (2017) support a longer term hypothesis, which takes into account both implementation costs and regulatory framework contingencies as well as skills, that will influence the pace and extent of the adoption process. Their estimations suggest that this will happen by 2055, indicating that it could also happen 20 years earlier or later depending on these factors and on the fact that automation susceptibility potential varies between occupations (Manyika et al, 2017, pp. 5–6). It should be noted that Autor (2015) revised his pessimistic forecasts of his 2013 paper by noticing that some tasks, of manual or of abstract nature, imply tacit rules which are difficult to translate into a set of explicit rules. In his view, despite the advent of self-driving cars and text analytics, Polanyis' paradox[9] is not going to be overcome in the short term since robots and software substitute some tasks but also complement some others which still need to be performed by humans. Furthermore, he points out that the quantity of jobs does not decrease by means of automation, but it may affect the quality of jobs available (Autor, 2015, p. 9). Finally, so far not many studies examine the impact of automation on demographic groups but a gender approach has been taken by Piasna and Drakoupil (2017) who observe that 'non-automatable tasks involve inter-personal contact and people skills, such as empathy, a feature of female-dominated personal services and care sectors, as well as creativity and critical thinking, more often required in male-dominated high-skilled professional jobs'.

Changes in the tasks structure

Irrespective of the amount of time it is going to take for automation to happen and the fact that many traditional jobs could persist in the future, future jobs would be a combination of technical tasks and non-routine tasks, where workers have comparative advantages: interpersonal interaction, flexibility, adaptability, and problem solving (Autor, 2015, p. 27). Automation of human input is strictly bound to the type of tasks that form a job or an

[8] Total of jobs susceptible to automation according to the authors above; Belgium 49%; The Netherlands 2-3 million jobs (conservative); UK 35%; EU average 54%; France 42%.

[9] 'We can know more than we can tell': there are actions and decision which humans perform unconsciously thus these rules become more difficult to infer and code.

occupation. A similar concept is used in the most recent European Jobs Monitor report by Eurofound (2016). It includes a set of indicators for measuring task content and methods across occupations in Europe. One of the key findings is that in recent years, routine task methods have declined (since most routine occupations decrease), while simultaneously traditionally non-routine occupations have become more prone to routinisation (Eurofound, 2016, p. 2). This process of routinisation of formerly non-routine jobs has interesting implications for the discussion about automation, because many occupations showing higher increases in routine are those that have been considered less at risk of automation so far. (Bisello and Fernández-Macías, 2016). Out of the available literature, Degryse (2016, p. 23) compiled an overview of jobs that are either at high risk or at low risk of automation as well as possible new jobs that might emerge. Jobs most at risks of automation include clerical tasks, sales, transport and logistics and manufacturing; jobs in education, management and HR, which require some kind of emotional intelligence skills are less at risk. Among the new jobs, top of the scale are specialists in data analysis, programmers and artificial intelligence scientists while low paid jobs are digital 'galley slaves'(data entry of content filtering) and platform economy workers.

Job polarisation and/or upgrading

Different authors strived to find a model which can explain the fact that difference in tasks and the different way they are bundled influence the type of jobs more prone to automation, and the quality of the job, low paid or highly paid. The skill-biased technological change (SBTC) hypothesis versus the routine-biased technological change (RBTC) hypothesis debate explores the issue of how automation relates to labour market shifts. The automation of work tends to polarise labour markets, especially for those jobs where machines' performances (stronger, faster, more accurate) are superior to humans: high levels of routine and precision are more likely to be found among jobs that require middling skill levels. Hence, technological changes entail rather a skills' polarising effect than an upgrading effect (Fernández-Macías and Hurley, 2016).

On the one hand, Goos et al (2014) show that the demand for mid-paid jobs decreases in comparison to high-paid and low-paid occupations because, first of all, current technological change is biased towards replacing labour in routine tasks and, second, there is the task offshoring phenomenon (Goos et al, 2014, p. 2509). The authors find that job polarisation appeared in 16 Western European countries and was pervasive across advanced economies (in the period of 1993-2010): whereas the highest-paying occupations show the fastest increases in their employment shares (for example, managerial, professional and associate professional occupations), the employment shares of occupations which pay about the median occupational wage (office clerks, craft and related trades workers, and plant and machine operators and assemblers) had dropped (Goos et al, 2014). Their model shows not only overall job polarisation, but also changes within and between industries. On the other hand, the findings by Frey and Osborne (2013) indicate that computerisation would mainly replace low-skill and low-wage jobs in the near future. Workers in low-skill jobs would reallocate to tasks that require creative and social intelligence as well as to tasks related to perception and manipulation; that is tasks that are non-susceptible to computerisation (Frey and Osborne, 2013, pp. 42–44). Arntz et al (2016) come to similar results finding a negative relationship between the automatibility of jobs and the educational job requirements. Education and the educational structure appears to play an important role for preparing people for the labour market, because 'automatibility strongly decreases in the level of education and in the income of the workers: It is mostly low skilled and low-income individuals who face a high risk of being automatable' (Arntz et al, 2016, p. 19). An explanation giving credit to the role of education institutions is presented by Oesch (2013): he argues that education institutions produced highly skilled workers which then prompted European firms to design their production towards certain tasks. He also explains that in some of the countries he considered, Switzerland, Denmark (less so in UK and Germany) the high level of the minimum wage might have prevented a large expansion of jobs in the low skilled category. It is also important to acknowledge that, as per many authors of inequality literature, boosting the supply of skills does not always lead to an improvement in job quality and that other factors such as institutional frameworks, the role of education and training, and the organisation of work play a part (Keep and Mayhew, 2014).

From the above, it seems that both the SBTC and RBTC approaches can be partially valid for Europe. These findings correspond to those of Eurofound's European Jobs Monitor (2014), which shows that between 1995 and 2007 there was a significant diversity of patterns of structural employment change in Europe. At least two dominant patterns can be identified, one of polarisation and one of upgrading, with perhaps a third category of mid-level upgrading (Eurofound, 2014, p. 37)[10]. Fernández-Macías (2015) takes up these finding and argues further that most of the diversity across countries and periods relates to middle and low-paid occupations (period 1995-2013). High-paid occupations, on the other hand, tended to grow in absolute and relative terms across most countries and periods. This would support the argument that recent technological change increases demand for high-skilled occupations but that, especially for Germany, the Netherlands and France, polarisation seems to have been caused by employment deregulation instead. In relation to other areas of Europe, a different pattern has been observed in some Central and Eastern European countries[11] (Keister and Lewandowski, 2017). The paper points to no decline in routine cognitive work (medium skilled workers) but it suggests that such workers may be particularly vulnerable as automation and technological change could affect these countries more significantly at some point in the future.

It seems that also for works based on US data, RBTC and SBTC explain job polarisation only partially. Dwyer (2013) argues that research focusing on technological change and weakening labour market institutions cannot explain crucial features of job polarisation in the US. Instead, she writes

> *'that theories of the rise of care work in the U.S. economy explain key dynamics of job polarization' showing that 'care work jobs contributed significantly and increasingly to job polarization from 1983 to 2007, growing at the top and bottom of the job structure but not at all in the middle'* (Dwyer, 2013, p. 390).

Furthermore, Mishel et al (2013) present results for the US and highlight that current SBTC models do not provide an explanation for main wage trends over the last three decades (Mishel et al, 2013, p. 4). They argue that technological and skill deficiency cannot adequately explain wage patterns and that technology might be a reason for widening wage inequality, but if so, it cannot be captured with current SBTC models (Mishel et al, 2013, p. 36).[12] A different approach has been taken in a study by Acemoglu and Restrepo (2017). They explored the relation between the adoption of robots and employment shifts for the US from 1993 to 2014.

[10] Especially for the period 2008-2010 the degree of diversity decreased and there was some convergence towards a polarising pattern. During 2011-2013 the employment shifts have been less polarising than in the former period and the aggregate shift pattern shows upgrading with some polarisation (Eurofound, 2014, pp. 31–37).

[11] Romania, Latvia, Lithuania and Poland.

[12] They find, using the U.S. Current Population Survey, that an 'occupational upgrading' has been taking place since the 1950s: while there is a decline in relative employment in middle-wage occupations and an increase in employment in higher-wage occupations, lower-wage occupations have remained a small and stable share of total employment, although growing in the 2000s (Mishel et al, 2013, p. 4). They demonstrate that there is no causal link between changes caused by technology and occupational employment patterns and wage inequality (Mishel et al, 2013, p. 5). Rather, 'a large and increasing share of the rise in wage inequality in recent decades (as measured by the increase in the variance of wages) occurred within detailed occupations.' (Mishel et al, 2013, p. 5). Because changes within occupations are central, occupational employment patterns are not sufficient to explain key labour market trends.

> *'According to our own estimates, one more robot per thousand workers reduces the employment ratio by about 0.18-0.34 percentage points and wages by 0.25-0.5 percent'* (Acemoglu and Restrepo, 2017).

Interestingly, and in contradiction with Autor's position, the authors find that disappearance of jobs in a sector did not translate into shift to another sector in the same or in the nearby geographical areas examined. A study with the same methodology for EU Member States has not been conducted yet. Nevertheless, some information about European companies was made by Jäger et al (European Commission, 2016, p. 58): they looked for the relation between productivity increases and employment in manufacturing companies using industrial robots. Their model shows that intensive use of industrial robots in manufacturing companies in high wage EU Member States seems to have the potential to improve the efficiency of manufacturing operations in those companies, and in parallel, to help safeguard manufacturing jobs.

From the review of the papers above it seems that RBTC and SBTC do not fully answer the question of the cause of polarisation. The phenomenon varies across countries and might also depend on the type of educational institutions and workers' skills present in the labour market.

Implications for job quality

In terms of implications for job quality there is no clear distinction between the discussions about automation and digitisation. However, as the term 'automation of work' refers to tasks previously performed by human labour that are now produced with capital, the debate mainly relates to the argument of upgrading or rather to the disappearance of 'bad[13]' jobs. The discussion also involves that working with robots has increased safety problems. Another issue identified is a shift in the framework of the relation between humans and machines in their work environment. These issues also bear the question: 'will human workers be instrumentalised and their roles determined by robots and their algorithms?' Degryse (2016) asks: 'Will we witness a reduction in physically demanding tasks, entailing benefits in terms of ergonomy for older workers? Or, on the contrary, will work paces become increasingly inhuman and the demands of the work environment ever more hellish?' (Degryse, 2016, p. 38). He poses further interesting questions giving some idea of the main points this discussion involves:

> *Will we see an 'emancipation' of workers from routine and repetitive tasks? Or a restriction of workers' room for manoeuvre or even freewill? Will the specific qualifications of these technicians be marginalised by the development of computerised maintenance and repair procedures? Will they have to be content with a job that requires them to follow up the diagnoses and carry out the repair procedures dictated by these machines? To paraphrase Head (2014) will smart factories make for dumber workers?* (Degryse, 2016, pp. 22, 39)

To structure the different findings and arguments in this section, the job quality index classification by Eurofound (2013) is used, it includes the dimensions:

1. intrinsic quality of work,
2. employment quality,
3. workplace risks,
4. working time and
5. work-life balance.

[13] Low-paid.

But first of all, to put automation technologies and job quality in context with Eurofound's classification, the relation between technological innovation and job quality is briefly described.

Relation between technological innovation and job quality

The relation between technological innovation and job quality is widely discussed in the literature: technological change increases productivity and in the long run most of the growth in productivity is explained by technological change (Autor, 2015; Muñoz-de-Bustillo et al, 2016, p. 10). Muñoz-de-Bustillo et al (2016) differentiate between technological changes leading to product innovation and those leading to process innovation. In the former case, the innovation of a new product may cause whole industries to disappear – and therefore the jobs and skills related to them. In the latter case, that is technological change leading to process innovation, developing new methods to produce old products is typically related to increased capital/labour ratios, which will cause a cut back in employment rates, examples are the automation of warehouses or the use of robots in industrial processes in welding and painting (Muñoz-de-Bustillo et al, 2016, p. 14). In the same study, Bustillo et al (2016) combined the theories mentioned in the work of Frey and Osborne (2013) and the Job Quality Index for Europe to examine whether occupations with higher probability of automation are regarded as having a higher or lower job quality according to the Job Quality Index. Under the assumption that Frey and Osborne's (2013) probabilities of automation are correct, technological change would reduce the amount of low quality jobs through the substitution of labour by capital, hence leading to an increase in the average job quality. This does not consider the question of employment shift to other sectors:

> *'whether the workers no longer demanded in those jobs increasingly computerised will find employment in other sectors of the economy, and what the quality of the new jobs performed by them will be.'*[14] (Muñoz-de-Bustillo et al, 2016, p. 17).

This issue is instead tackled by Acemoglu and Restrepo (2017) for the US labour market.

Intrinsic quality of work

Intrinsic quality of work (skills, autonomy and social support) could change due to human robot interaction (HRI). Depending on how it is implemented, it could make job quality better in terms of more interesting tasks or, on the contrary, make tasks boring and repetitive, provoking workers' autonomy loss. The literature presents arguments for both scenarios, briefly illustrated below.

Manyika et al (2017) write that more integration with technology will free up time for human workers allowing them to focus more on activities to which they bring skills that machines have yet to master. This could make work harder to organise, more complex, and would require spending more time on coaching (Manyika et al, 2017, p. 114). A broad debate on the challenges and features of the collaboration between humans and robots is discussed under the term human-robot-interaction (HRI) (for an overview of this debate see Moniz and Krings, 2016; Sheridan, 2016). Collaborative robots raise new questions and challenges entailing an adaptation of workplace design and organisational models, mostly in terms of increased complexity of decision-making. Robotic systems in manufacturing, for example, raise the question of how to integrate the organisation of complex tasks with several workers in different workstations. The chance that an existing production model will continue to be used after the introduction of robots is very high, since system developers often only provide technical solutions, but no organisational solutions.

More collaboration with robots can also create new risks. As already pointed out by Adam Smith in 1776, one of the consequences of the process of the division of labour is the loss of the understanding of the greater picture and the repetitiveness of performing a few simple tasks. Workers could become 'as stupid and ignorant as it is possible for a human creature to

[14] In this case computerisation is used as a synonym of automation.

become' (Smith in Muñoz-de-Bustillo et al, 2016, p. 19). In this context Degryse (2016) adds that through recent and future technological changes in industry, the risks involve a conflict between the machine and the worker: the rhythm of the machine, as already happened in the Taylorist model, could dictate a worker's timing take away its autonomy.

AI and robotics might also change human interaction: some fear that there could be an increase in social isolation due to the fact that workers might have to spend most of the time interacting with machines (Butrimas in Smith and Anderson, 2014, p. 30). Hinds et al (2004, pp. 173–174) examine the attitudes towards robots and the use of robots and suggest that there are significant differences in the extent to which people will rely on robots compared to reliance on human colleagues with more trust placed on humans.

Skills

As already highlighted above, SBTC examines the hypothesis that recent technological changes in production favour skilled workers over unskilled workers since the use of computers is more widespread in highly paid jobs and requires skilled workers Bessen (2015) shows that occupations which are automated provoke an employment shift and require the acquisition of new skills by workers. As the costs for learning new skills are high, it leads to 'greater within-occupation wage inequality' (Bessen, 2016).

The upgrade in occupations type could imply that robots would assist humans and 'allowing humans to use their intelligence in new ways, freeing us up from menial tasks' (Shlain in Smith & Anderson 2014, p.13). Valsamis et al (2015, p. 36) take a more nuanced approach saying that in a polarised labour market there is a need for medium-skilled workers able to upgrade their skills to qualify for higher-skilled jobs and to be employable. However, some social groups, especially older workers and people with lower than upper secondary education, lack e-skills, that is ICT skills that are crucial to stay employable and can range from highly proficient skills such as developing to digital literacy skills such as using emails or navigating on the internet. According to data from the European Commission, one in two workers in the European Union does not have a sufficient level of e-skills[15]. As e-skills and competitiveness are directly and positively related, this has to be seen as highly problematic. Moreover, the number of vacancies in ICT-related sectors is expected to increase up to 500,000 vacancies by 2020 (European Commission, 2017). Additionally, e-skills are not only needed in other sectors and occupations, but also during the job search process. Besides e-skills, other generic skills like social intelligence and computational thinking will become increasingly important to be employable (Valsamis et al, 2015). Other skills identified as key skills for workers of the future in the literature are creativity, social intelligence and entrepreneurial thinking (Eichhorst et al, 2016, p. 4; Smith and Anderson, 2014). High-skilled workers who work with technology, in particular robot users (Moniz and Krings, 2016), are likely to be in strong demand. Taking into account that increasing Human Robots Interaction (HRI) could involve new work practices, internally reallocating over-skilled workers, or retraining low-skilled workers, HRI may also result in more creative input from operators, more responsibility, and an improvement in the quality of work (Moniz and Krings, 2016, p.

[15] 'The term 'e-skills' is defined as covering three main Information and Communication Technologies (ICTs) categories:

a. **ICT practitioner skills** are the capabilities required for researching, developing, designing, strategic planning, managing, producing, consulting, marketing, selling, integrating, installing, administering, maintaining, supporting and servicing ICT systems.
b. **ICT user skills** are the capabilities required for the effective application of ICT systems and devices by the individual. ICT users apply systems as tools in support of their own work. User skills cover the use of common software tools and of specialised tools supporting business functions within industry. At the general level, they cover 'digital literacy'.
c. **e-Business skills** correspond to the capabilities needed to exploit opportunities provided by ICT, notably the internet; to ensure more efficient and effective performance of different types of organisations; to explore possibilities for new ways of conducting business/administrative and organisational processes; and/or to establish new businesses' (Eurostat Glossary: e-skills).'

15). In terms of skills, transformation due to automation involves new qualification needs, new technical competences, and organisational competences with regard to working in teams, competences in communication, and decision processes within work processes (Brynjolfsson and McAfee, 2011; Manyika et al, 2017; Moniz and Krings, 2016, p. 2). A negative scenario regarding the implications of this process is instead painted by Roubini (2015); he predicts that manufacturing jobs will be obliterated by machines, therefore making human skills unnecessary:

> *‘The risk is that workers in high-skilled, blue- collar manufacturing jobs will be displaced by machines before the dust settles at the end of the Third Industrial Revolution. We may be heading toward a future where factories consist of one highly skilled engineer running hundreds of machines – with one worker left sweeping the floor… until that job is given to an industrial-strength Roomba Robot’* (Roubini in Degryse, 2016, p. 21).

It will be important for young Europeans, when they make education and career choices, to be aware of the drivers of automation in specific sectors, so they can identify the skills that might be useful for them to acquire from a labour market perspective. (Manyika et al, 2017, p. 114; Bessen, 2016, p.31). For this reason, Arntz et al (2016) stress the need to focus on the potential inequalities and requirements for retraining rather than the threat of employment losses (Arntz et al, 2016, p. 25). However, it might not be so easy to retrain a large part of the workforce. Baldwin’s most recent work (Fontagné and Harrison, 2017, pp. 52–60) adds to the automation debate two policy remarks valid for the EU: first, the shift from manufacturing to ‘compu-facturing’ and the shifts of the steps of production where value is added , the so called value added ‘smile’ curve[16]), are changing the employment landscape forever, not only by polarising the market but also by eliminating the traditional gradual path of skills acquisition which made possible for a low-skilled worker to evolve with time and on-the-job experience into a high skilled machinist. Second, the specialisation required by ‘compu-facturing’ and the nature of high tech jobs, flourishing in places where ideas can be exchanged fast and face-to-face meetings are facilitated, will favour locations offering access to a vast talent pool. For this reason Baldwin argues, agreeing with Moretti (2012), that cities will be the factories of the 21st century.

The majority of the works presented in this literature review seems to point out that the most required skills in the future will be those which enable collaboration and communication both human-to-human and human-to-machine. This observation should be looked at keeping in mind that part of the literature brings evidence that ‘boosting skill supply on its own doesn’t have a significant impact on the way that organisations design jobs and make use of skills’. Regulations instead might have an impact on pay and potentially on work organisation (Lloyd and Payne, 2016) as well as the political educational and social dialogue framework of a country. Thus, job quality might not necessarily improve linearly along with the requirement of higher skills.

Workplace risks

Safety is an important factor in human-robot relations, since robots also represent a potential hazard. Robots can perform powerful and sudden movements that can cause risks for humans surrounding them. They can move their arms or bodies powerfully and very rapidly, and they often operate with dangerous and sharp tools. The operation of industrial robots is already regulated by standards. (Vasic and Billard, 2013, p. 1). The ISO standard on collaborative robots addresses these aspects, such as the ISO/TS 15066. These standards not only refer to the ergonomic dimension, but also emphasise organisational issues including the question

[16] The traditional value added curve (Shih, 1992) is going to increase only for R&D and design in pre-production and for marketing and services in post-production, while production value added will stay the same or decrease (Baldwin, 2012). It is called ‘smile curve’ because it resembles a smile.

whether workers should perform more qualitative tasks or should be integrated in 'group work' concepts (Moniz and Krings, 2016, p. 7).

Vasic and Billard (2013) also call for definitions of robots and specific safety guidelines to be addressed urgently by the scientific and industrial community. They identify autonomous vehicles and mobile robots as two of the most urgent areas where safety guidelines would be needed. A solution to limit the risks robots may cause is to impart moral guidelines to a robot's software. This idea is not new, at least it existed in a fictional context for a while. In the short story collection 'I, Robot' (first published 1950), the science fiction author Isaac Asimov introduced his 'Three Laws of Robotics'; that is a set of guidelines for robot behaviour[17]. On the non-fiction side, McDonald (2015) reports that roboticists and engineers at Berkeley and elsewhere are dealing with the issue of robots' moral behaviour. Caution should be paramount, since 'doing so could be a double-edged sword. While it might mean better, safer machines, it may also introduce a slew of ethical and legal issues that humanity has never faced before — perhaps even triggering a crisis over what it means to be human' (McDonald, 2015). The MIT is also looking into ethics of Artificial intelligence with the 'Moral machine' project[18]. The moral machine is a set of questions involving the moral choices that need to be embedded in an algorithm for self-driving cars. The questions to the visitors of the moral machine website imply ethical choices that should be made by the algorithm, for example saving the passenger or the pedestrian crossing in front of the car, in case of green light or red light for the car. This type of issues have prompted Stephen Hawking and other scientists to call for policy makers to regulate the field of AI as soon as possible[19] (Future of Life Institute, 2015).

The challenges posed by further developments in the AI field have also been taken into consideration by internet major players such as Google, Amazon, Facebook and Apple which, in 2016, founded the 'Partnership on AI' (Partnership on Artificial Intelligence, 2016) a partnership open to both profit and non-profit companies and to the academic world, wishing to discuss and self-regulate AI impact on all aspects of human life. The partnership work will focus on six thematic pillars: safety-critical AI, fair transparent and accountable AI, collaboration between people and AI, AI labour and the economy, social and societal influences of AI, AI and social goods.

It seems the great absent from the AI table discussion are governments. However, some attempts to tackle the issue from a regulatory perspective have been, in this context, the draft of a set of regulations urged by the European Parliament to govern the use and creation of robots and artificial intelligence. This includes a form of 'electronic personhood' to ensure rights and responsibilities for robots. It is also proposed that robots should be equipped with emergency 'kill switches' to prevent them from causing extreme harm (Hern, 2017). Even if this is outside of the scope of this literature review it is important to make a reference to the impact of AI within the wider issue of society control and individuals' privacy: automation of work can lead to an extensive collection of workers' data and the extent to which this is allowed will also depend on regulatory frameworks. Two big changes of opposite nature are being implemented during 2017 on privacy regulations, 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).

Working time and work-life balance

Technological developments might change the notions of work and employment (for example, stronger focus on small-scale or artisanal modes of production, shorter working

[17] The first law is not to harm human beings; the second, to obey human orders; and the third, to protect the robot's own existence. In Asimov's story, these guidelines lead to conflicting directives and finally drive the robot insane.

[18] http://moralmachine.mit.edu/

[19] https://futureoflife.org/ai-open-letter

hours and more time to spend on leisure, etc.), and the concept of a job as a means of the distribution of wealth (Smith and Anderson, 2014, p. 5,13). Workers may be also able to take advantage of new opportunities for independent work as the corporate landscape shifts and more project work is outsourced by big companies (Manyika et al, 2017, p. 114). This might suit some part of the population but not everybody might want to work in small scale production or as a self-employed due to the higher insecurity. Recalling Rifkin's suggestion (Rifkin, 2005) that the working week should become shorter and shorter to distribute work differently, of the possible outcomes could be that a more *'humane restructuring of the general social contract around* employment' that is to give people access to basic needs and safe places to live (Bray in Smith & Anderson 2014, p.14).

And the risk is indeed real, the utopian vision could also turn dystopian: advantages may apply only to individuals in already secure jobs or who have substantial assets and difficulties may be faced by those who end up being displaced or losing their job due to automation or recombination of tasks. If workers (particularly the low-skilled or those who do routine tasks that can be automated) keep their job, surely they will be re-assigned to other tasks or multiple tasks but not necessarily more pleasant or less stressful (Drahokoupil and Jepsen, 2017).

Implications for social policy

The impact of automation on the funding and delivery of social security and social policies is perceived differently depending on the foreseen changes in the labour market, with some authors foreseeing a loss of jobs and revenue[20].On the basis of these pessimistic scenarios, West (2015) argues that an increase in unemployment due to automation makes necessary disentangling eligibility to disability and pension benefits from employment status, in a similar manner to the flexicurity model in the Nordic countries. In addition to that, Colin and Palier (2015) point out that the loss of jobs could diminish social security contributions from labour. This could create a crisis in welfare systems, which are based on having most of the adult population employed and paying taxes. Within the context of casualisation of work, intermittent employment increasingly emerging on European labour markets (De Stefano, 2016), social policies should focus not only on the unemployed, but also on the underemployed. Goldin (2015) suggests financing social security by raising top marginal income tax rates, increasing capital income tax rates, introducing wealth taxes and reducing tax avoidance. Duchatelet (2017) points out the need to offset the loss in funding by other means than taxing (low wage) labour. He suggests reducing the costs of social security administration through efficiency gains and using the profits of state owned companies to fund social security. He argues that the redistributive logic behind social security funding needs to be reconsidered and advocates for higher taxes on areas such as energy consumption as well as in gambling, alcohol and tobacco. He is also in favour of a tax on products made by robots (by increasing the VAT and/or the sales tax).

This 'robot tax' has been proposed by several policy makers and prominent figures in the digital industry. Bill Gates advocated for this tax as a way of slowing down automation and funding jobs in care for the elderly and childcare (Quartz, 2017). Having robots paying tax and making contributions to social security was also proposed by the European Parliament's committee on legal affairs in 2016. This proposal received widespread media attention and was rejected by the European Parliament in February 2017. The European Commissioner for Digital Single Market and Vice President of the European Commission, Andrus Ansip, has also rejected a robot tax.

A common objection against the robot tax is that it puts an additional burden on investments in a context of economic slowdown and a lack of investment, notably due to austerity policies. A tax that would increase the costs of robots in a context of cheap human labour

[20] A variation to this would be a study by Acemoglu and Restrepo (2017), which shows that there is no relationship between population ageing and slower growth of GDP per capita. This is due to the fact that countries with a more rapid ageing of the population have incorporated more robots in production processes.

would delay increases in productivity (The Economist, 2017). Varoufakis (2017) sees a number of practical problems if this tax was to be implemented. First, whilst the wages paid to workers change over time, it's uncertain if the reference salary to determine the robot tax would be fixed or if it could be changed in an arbitrary manner. Secondly, the creation of robots operating machines that have never been operated by humans means that there would not be a reference salary to calculate such tax. Justifying a tax on robots but not on other types of machinery is also problematic. Lastly, a lump sum tax at the point of sale instead of an income tax would incentivise producers to bundle robots with other machinery/capital goods. This reflects the point made by other critics regarding the difficulties of making a differentiation between robots and other technological advancements. For example, Zhang (2017) points out that tax authorities would need to make 'the perhaps impossible distinction between labor-saving machines and labor-enhancing ones' and to change the approach to taxing business investment in equipment. Summers (2017) opposes the tax on the grounds that robots do not only increase output but also produce better goods and services and therefore further taxation would stifle innovation. He argues for better redistribution of wealth rather than hindering growth or drive production offshore. His preference for addressing structural joblessness through the public sector and the 'need to take a more explicit role in ensuring full employment' links with proposals advocating for the government being an employer of last resort through a job guarantee. For example, Meyer (2017) proposes job guarantee schemes with requalification/retraining as a key component that could be used to strengthen the health and social care sectors[21].

Other alternative taxation schemes in the digital economy have been suggested in the past, such as the 'bit tax' proposed by Soete and Kamp (1996). It was inspired by the 'Tobin tax' on financial flows and followed the same principle: a very small percentage of taxation on network exchanges of digital data, aimed at feeding social security systems under threat. The proposal was not taken up due to the criticism of the IT industry. Another proposal that is gaining momentum in the debate about the impact of automation on social policy is the (tax free) universal basic income, with pilot projects taking place in Scotland (The Guardian, 2017a), Finland (The Guardian, 2017b) and elsewhere outside of Europe. Advocates for this type of support argue that it could be funded by taxes on business profits, air pollution and on big fortunes (Clifford, 2016). Duchatelet (2016) suggests that a share of this income should not be means tested and solely based on age, whilst the other would be provided in relation to specific needs or circumstances. Those against this idea argue that it would entail huge costs and that its implementation would not ensure that recipients would choose or be able to afford healthcare or housing (Colin and Palier, 2015). There are also concerns as to whether such income is an adequate substitute to employment and whether it would blunt incentives to contribute productively to society (Rahbari et al, 2016).

Implications for social dialogue and industrial relations

Efficient and smooth implementation of digital transformation and technological change should be a traditional role of industrial relations, social dialogue and collective bargaining, as it was in the 1990s with the introduction of ICT. In some industrial sectors, automation and robotisation are not totally new phenomena. Sam Hägglund, General Secretary of the European Federation of Building and Woodworkers (EFBWW), notes that the use of robots is not new in the building sector, where hard physical work is the norm. Robots have been used by architects since the 1970s and now increasingly for the actual building work itself (ETUI-ETUC, 2016).

What is different now, as described in the previous sections, is the spreading of automation across many occupations and sectors. The implications of automation, that is the use of robots in industry and services, on industrial relations are huge as implementing automation

[21] In relation to welfare, Keister and Lewandowski (2017) point out the particular importance of having universal access to early childhood education and care in order to acquire the skills necessary to enter occupations involving non-routine cognitive tasks, which are more difficult to automate than cognitive routine work.

processes strongly affects the status quo of the main actors, that is the social partners and the state at all levels. On the one hand, employers and employers' organisations, and trade unions or workers' representatives have to deal with digital change and automation at company or sector level. Equally, the state may intervene by regulating certain aspects of the implementation of automation and in a broad sense, digitalisation. In Germany, unions like Verdi have put digital transformation at the heart of the service union's activity (Planet Labor, 2015). IG Metall is supporting the initiative 'Arbeit 2020 in NRW' launched by the employment ministry in North Rhine-Westphalia, aimed at drawing up a 'company digitalisation map': for example, how much of the work process is automated, the impact of these processes on jobs within the department, and the level of training given to employees. They are also setting out an action plan, so the process of digitalisation and the shift in training needs at the firm is subject to continuous discussions with social partners (Planet Labor, 2017). At EU level, ETUC has acknowledged digitalisation broadens the possibilities for automation, robotisation and outsourcing in industries and services, and trade unions are challenged to shape the transition to fair and good digital work. The involvement of trade unions is a major challenge as well as an opportunity (ETUI-ETUC, 2016). Managing a fair transition to a digital economy is necessary and the Trade Union Advisory Committee (TUAC) to the OECD is drawing up a trade union response to digitisation which includes, among other elements, social dialogue and democratic consultation of social partners and stakeholders (Page, 2017).

This approach with regard the introduction of digital technology notably in the manufacturing sectors – although not exclusively – has been adopted by national authorities and governments under the label 'Industry 4.0'. Germany pioneered with the Green Paper *Work 4.0: Re-imagining work* (Bundesministerium für Arbeit und Soziales, 2015) in which the Industry 4.0 approach was stressed as part of the social dialogue. Many other governments also have started to develop similar initiatives aimed at triggering debates and applying measures to develop the potential of technology and digitalisation in the manufacturing sector (Eurofound, 2016, 2017). Issues discussed in these national initiatives are commonly related to the impact of technological changes on sector, production processes, employment, workplaces and safety issues, working time concepts and qualifications needed. The implementation of these initiatives is very uneven, depending on the weight of the industry, digital development and political willingness. The debates in Germany, for example, focus mostly on the expansion of flexibility (working time, work organisation).

Even though social partners show different approaches to the implementation of digital change, for example, employer organisations' more willing to avoid any further regulation, concerns on the skills needed by businesses and workers in the digital age are widely shared by both sides of the industry. To this extent, they strongly demand national and European strategies, policies and investments to qualify people and reskill workers. The introduction of automation and robotisation typically belongs to both the bipartite collective bargaining at company and sector level between unions and employers, and the institutional social dialogue, via the educational and vocational training systems. The 2015-2017 Work Programme of the EU social partners recognises that 'social partners will exchange views on the specific issue of digital skills, including the role of digital and distance learning, open educational resources, e-services. The exchange should include training and qualification pathways and best practices' (BUSINESSEUROPE, ETUC, CEEP and UEAPME, 2015). Coinciding with the Tripartite social summit in March 2016, same EU social partners signed a 'Statement on digitalisation' with no specific action or commitment, but a general call to EU institutions and the relevant Commissioners to work hand-in-hand with the social partners to define an ambitious and coherent EU agenda.

On the contrary, research reviewed by the OECD (2017) on the effect of technology suggests a different role of the unions combined with other labour market institutions: stricter employment protection and stronger unions might be expected to slow down employment adjustments. According to these researchers (Breemersch and Damijan, 2017), the strength of trade unions, the strictness of employment protection legislation and the minimum wage (measured by the Kaitz index)[22] might alter the effect of technology and globalisation on the labour market, although the direction of the effect is theoretically ambiguous. On the other hand, firms might be more likely to use technology to replace workers when facing the rigidities imposed by stricter regulations or stronger unions. Some authors show that the higher costs generated by overly strict labour market regulations can induce firms to increase their capital intensity (Alesina and Zeira, 2006). In addition, according to the OECD research review (2017), it is plausible that even for a given level of capital intensity, firms facing rigidities generated by regulation or unions might be more likely to use technology to replace rather than complement workers.

Social dialogue and collective bargaining as core elements of the industrial relations system should serve to share the wealth created by digital transformation. Automation and robotisation may interfere on most grounds where labour and capital settle power and discretion. Automation deployment affects core elements of the employment relations: productivity (where do the productivity gains go if they are not shared within workers' wages?); employment status, new recruitment, skills policy and training; working time and occupational health and safety, among others. In short, every topic in which workers' representatives and/or trade unions and management are usually devoted to negotiate within social dialogue frameworks in industrial relations systems in Europe. Following this reasoning, automation processes raise the question of how to integrate and include workers in the move towards inclusive and intelligent robotisation, that is, the issue of specific workers' participation (Degryse, 2017). Apart from the individual aspects concerning the quality of employment, automation also touches upon collective implications in the context of effects on collective bargaining or on the information and consultation procedures within the workplace.

Degryse (2017) stresses that industrial robotisation does not only affect industry and manufacturing, but also the services sector. Automation and dematerialisation of increasing numbers of tasks in trade, distribution, banking, insurance and other sectors (automatic document reading, content management, procedure and process automation, etc.) bring about profound changes in the organisation of work and undoubtedly a gradual erosion of traditional employment in these sectors.

Conclusions

It is clear that the future of EU workers will be influenced by technological change. The challenge identified is to find the factors which allow to correctly estimate which jobs or tasks will change or disappear, and how soon this will happen. It seems that a mix of the RBTC and SBTC models is needed to explain the situation in European Member States where there are different institutional contexts and employment levels. Further, the answer to the competition human versus robots is still debated among academics: will robots make jobs disappear or will these jobs morph into new ones (in the same sector or in another one) with tasks which require more interpersonal skill? Or will robots favour a type of work where meaningful human intervention is kept at minimum? For sure, as pointed out by Baldwin and hinted by many others, the gap between ICT skilled and unskilled workers will widen making the traditional path of incremental upskilling on the job a thing of the past. Perhaps is worth making explicit that under the automation umbrella there are different strands which are, at times, treated together as one, that is automation can mean robots only or robots and software combined or AI tools, so the common denominator for automation becomes the fact that a task previously performed by human workers can now be performed without or with minimum input on their part. It is also worth mentioning that, through Industry 4.0, changes in tasks might entail changes of the overall production process which in the context of

[22] The Kaitz index is an economic indicator represented by the ratio of the nominal legal minimum wage to the average wage.

Eurofound's Digital Age activity, a set of research projects looking at the implications of new technologies on the world of work, is defined as digitalisation of processes[23] .

Another point strongly emerging from this literature review is the impact not only on work and workers but on society at large. Changes in investment will challenge the current organisation of labour and the type of investments enterprises will make: if investments concentrate on machines and powerful software, the wealth produced will not be shared among as many workers as before, triggering debates around the distribution of wealth in the society. Employment changes would influence social policy and call for health and safety regulations of new occupations, for guidelines on interactions with 'humanoid' colleagues and forward looking plans for income distribution in a society that could see an increased part of its population, if not all, being unemployed.. However, what is the case now at this very early stage of automation change? How may industrial relations fit and meet their role with digital transformation taking place at this fast pace? For what concerns workers' positions on the impact of automation on their work, there are still few studies on the effects of current automation on workers although in 2016 and 2017 some trade unions (in Germany and in Italy) have started to survey their affiliates to understand the phenomenon better. Research so far has mainly focussed on the individual aspects of these transformations, and much less on the collective aspects of the employment relationship. The implications of automation for social partners' strategies and social dialogue at sector and company level, including the role of collective bargaining shaping and easing the implementation of digital changes, deserve to be studied in-depth.

[23] The digitisation of production and distribution processes refers to the use of sensors and rendering devices to translate (parts of) the physical production process into digital information (and vice versa), and thus takes advantage of the massively enhanced possibilities of processing, storage and communication of digital information.

References

All Eurofound publications are available at www.eurofound.europa.eu

Acemoglu, D. (2002), "Technical change, inequality, and the labor market", *Journal of Economic Literature*, Vol. XL (March 2002), pp. 7-72.

Acemoglu, D. and Restrepo, P. (2016), "The Race Between Machine and Man: Implications of Technology for Growth, Factor Shares and Employment", *NBER Working Paper No. 22252*.

Acemoglu and Restrepo. (2017), "Robots and Jobs: Evidence Form US and the Labour Markets", *NBER Working Paper No. 23285*.

Alesina, A. and Zeira, J. (2006), "Technology and Labour Regulations", *NBER Working Paper No.12581*.

Arntz, M., Gregory, T. and Zierahn, U. (2016), "The Risk of Automation for Jobs in OECD Countries", *OECD Social, Employment and Migration Working. Papers, No. 189*, OECD Publishing, Paris.

Autor, D. H. (2003), "The Skill Content of Recent Technological Change: An Empirical Exploration", *Quarterly Journal of Economics*, Vol.118, No.4, November 2003, pp.1279-1334.

Autor, D.H. (2013), "The 'Task Approach' to Labor Markets: An Overview.", *Journal for Labour Market Research*, Vol. 46 No. 3, pp. 185–199.

Autor, D.H. (2015), "Why are there still so many jobs? The history and future of workplace automation", *The Journal of Economic Perspectives*, Vol. 29, No. 3, Summer 2015, pp. 3–30.

Baert, A. and Ledent, P. (2015), "La Révolution Technologique En Belgique", *ING FOCUS-Emploi*, ING, Bruxelles.

Bessen, J.E. (2016), "How Computer Automation Affects Occupations: Technology, Jobs, and Skills", *Boston University School of Law, Law & Economics Working Paper No. 15-49*, Boston University.

Bisello, M. and Fernández-Macías, E. (2016), "Fewer Routine Jobs But More Routine Work", *Social Europe*, September 26.

Bowles, J. (2014), "The computerisation of European jobs", *Bruegel Blog*, available at: http://bruegel.org/2014/07/the-computerisation-of-european-jobs/ (accessed 11 August 2017).

Breemersch, K., J.P. Damijan, and J.K. (2017), "Labor Market Polarization in Advanced Countries: Impact of Global Value Chains, Technology, Import Competition from China and Labor Market Institutions", *OECD Social, Employment and Migration Working Papers 197,* OECD Publishing.

Brynjolfsson, E. and McAfee, A. (2011), *Race Against The Machine: How the Digital Revolution Is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy*, edited by Digital Frontier Press, Lexington, Massachussets.

Buduma, N. and Locascio, N. (2017), *Fundamentals of Deep Learning: Designing Next-Generation Machine Intelligence Algorithms*.

Bundesministerium für Arbeit und Soziales (2015), *Re-Imagining Work 4.0*, available at: http://www.bmas.de/SharedDocs/Downloads/DE/PDF-Publikationen/arbeiten-4-0-green-paper.pdf;jsessionid=722E334C2DAC3E95CDE2530DFAEEAEF0?__blob=publicationFile&v=2 (accessed 29 August 2017).

BUSINESSEUROPE, ETUC, CEEP and UEAPME (2015), "THE 2015-2017 WORK PROGRAMME OF THE EUROPEAN SOCIAL PARTNERS", available at: https://www.etuc.org/sites/www.etuc.org/files/publication/files/final_joint_social_dialog ue_work_programme_2015_2017.pdf (accessed 29 August 2017).

Carlson, M. (2015), “The Robotic Reporter”, *Digital Journalism*, Routledge, Vol. 3 No. 3, pp. 416–431.

Clifford, C. (2016), “Elon Musk says robots will push us to a universal basic income—here’s how it would work”, *CNBC.com,* available at*:* https://www.cnbc.com/2016/11/18/elon-musk-says-robots-will-push-us-to-a-universal-basic-income-heres-how-it-would-work.html (accessed 29 August 2017).

Codella, N., Nguyen, Q.-B., Pankanti, S., Gutman, D., Helba, B., Halpern, A. and Smith, J.R. (2016), “Deep Learning Ensembles for Melanoma Recognition in Dermoscopy Images”, IBM Journal of Research and Development, Vol. 61, No. 4/5.

Colin, N. and Palier, B. (2015), “The Next Safety Net. Social Policy for a Digital Age”, *Foreign Affairs”*, July/August 2015 Issue.

De Stefano, V. (2016), “The rise of the ‘just-in-time workforce’: On-demand work, crowdwork and labour protection in the ‘gig-economy’”, *ILO, 2016 Conditions of work and employment series; No. 71*, ILO, Geneva.

Degryse, C. (2016), “Digitalisation of the Economy and its Impact on Labour Markets”, *ETUI Research Paper - Working Paper 2016.02*.

Degryse, C. (2017), “Shaping the World of Work in the Digital Economy”, *ETUI Foresight Briefs* , No. 1, ETUI, Brussels.

Deloitte (2014), *De Impact van Automatisering Op de Nederlandse Arbeidsmarkt*, Deloitte.

Deloitte (2015), *From brawn to brains. The impact of technology on jobs in the UK*, Deloitte, p. 11.

Dickerson, P., Robins, B. and Dautenhahn, K. (2013), “Where the action is: A conversation analytic perspective on interaction between a humanoid robot, a co-present adult and a child with an ASD”, *Interaction Studies*, Vol. 14 No. 2, pp. 297–316.

Drahokoupil, J. and Jepsen, M. (2017), “The digital economy and its implications for labour. 1. The platform economy”, *Transfer: European Review of Labour and Research*, Vol. 23 No. 2, pp. 103–107.

Duchatelet, R. (2016), “Re-inventing social security”, *Basic Income News*, available at: http://basicincome.org/news/2016/11/re-inventing-social-security/ (accessed 28 August 2017).

Duchatelet, R. (2017), “Funding social security after automation”, *Basic Income News,* available at: http://basicincome.org/news/2017/01/funding-social-security-automation/ (accessed 28 August 2017).

Dwyer, R.E. (2013), “The Care Economy? Gender, Economic Restructuring, and Job Polarization in the U.S. Labor Market”, *American Sociological Review*, SAGE Publications Sage CA, Los Angeles, CA, Vol. 78 No. 3, pp. 390–416.

Eichhorst, W., Hinte, H., Rinne, U. and Tobsch, V. (2016), “How Big Is the Gig? Assessing the Preliminary Evidence on the Effects of Digitalization on the Labor Market”, *IZA Policy Paper No. 117*, IZA.

ETUI-ETUC. (2016), “Resolution on digitalisation: ‘towards fair digital work’. Adopted by the Executive Committee on 8-9 June 2016.”, available at: https://www.etuc.org/documents/etuc-resolution-digitalisation-towards-fair-digital-work#.WaSYtk3wtzM.

Eurofound (2013), *Employment polarisation and job quality in the crisis: European Jobs Monitor 2013*, Eurofound, Dublin.

Eurofound. (2014), *Drivers of Recent Job Polarisation and Upgrading in Europe, European Jobs Monitor 2014,* edited by Publications Office of the European Union, Luxembourg.

Eurofound (2016), *What do Europeans do at work? A task-based analysis: European Jobs Monitor 2016*, Publications Office of the European Union, Luxembourg.

Eurofound, (2017), “The Impact of Advanced Industrial Robotics on European Manufacturing: Taking Human-Robot Collaboration to the next Level”, *Future of Manufacturing in Europe*, Dublin.

European Commission (2016), *Analysis of the Impact of Robotic Systems on Employment in the European Union – Update*, Publications Office of the European Union, Luxembourg.

European Commission, (2017), *High-Tech Leadership Skills for Europe*, available at: http://eskills-scale.eu/fileadmin/eskills_scale/all_final_deliverables/scale_e-leadership_agenda_final.pdf (accessed 18 May 2017).

Fernández-Macías, E.(2015), “Job Polarisation In Europe: Are Mid-Skilled Jobs Disappearing?”, *Social Europe*, July 30.

Fernández-Macías, E. (2017), *Automation, digitisation and platforms: Implications for work and employment. Concept paper*, Eurofound working paper, Dublin.

Fernández-Macías, E. and Hurley, J. (2016), “Routine-biased technical change and job polarization in Europe”, *Socio-Economic Review,* Vol. 15, No. 3, 1 July 2017, pp. 563–585.

Financial Times (2017), “Fund managers deny AI threatens jobs”, 14 August.

Fontagné, L. and Harrison, A.E. (2017), *The Factory-Free Economy Outsourcing, Servitization, and the Future of Industry,* Oxford University Press.

Frey, C. and Osborne, M. (2013), *The future of employment: how susceptible are jobs to computerisation*, University of Oxford.

Future of Life Institute (2015), *AI Open Letter - Future of Life Institute*, available at: https://futureoflife.org/ai-open-letter (accessed 19 May 2017).

Goldin, I. (2015), “The Future of Work”, *Huffington Post*, available at: http://www.huffingtonpost.com/ian-goldin/the-future-of-work_1_b_6802184.html (accessed 28 August 2017).

Goos, M., Manning, A. and Salomons, A. (2014), “Explaining job polarization: Routine-biased technological change and offshoring”, *American Economic Review 2014*, Vol. 104, No. 8, pp. 2509–2526.

Hahsler, M., Grün, B., Hornik, K., Wien, W. and Buchta, C. (2005), “Introduction to arules – A computational environment for mining association rules and frequent item sets”, *Journal of Statistical Software*, Vol. 14 No. 15.

Hern, A. (2017), “Give robots ‘personhood’ status, EU committee argues”, *The Guardian*, January 12.

Hinds, P.J., Roberts, T.L. and Jones, H. (2004), “Whose Job is it Anyway? A Study of Human-Robot Interaction in a Collaborative Task”, *Human-Computer Interaction*, Vol. 19, pp. 151–181.

International Federation of Robotics (2016), *World Robotics 2016*, available at: https://ifr.org/worldrobotics/.

Keep, E. and Mayhew, K. (2014), “Inequality – ‘wicked problems’, labour market outcomes and the search for silver bullets”, *Oxford Review of Education*, Routledge, Vol. 40 No. 6, pp. 764–781.

Keister, R. and Lewandowski, P. (2017), “A routine transition in the digital era? The rise of routine work in Central and Eastern Europe”, *Transfer: European Review of Labour and Research*, Vol. 23 No. 3, pp. 263–279.

Lloyd, C. and Payne, J. (2016), *Skills in the Age of Over-Qualification: Comparing Service Sector Work in Europe*, 2017th ed., Oxford University Press.

Manyika, J., Chui, M., Miremadi, M., Bughin, J., George, K., Willmott, P. and Dewhurst, M. (2017), *A Future that Works: Automation , Employment , and Productivity*, McKinsey Global Institute.

McAfee, A. and Brynjolfsson, E. (2014), *The Second Machine Age*, WW Norton & Company, New York.

McDonald, C. (2015), "The Good, The Bad and The Robot: Experts Are Trying to Make Machines Be Moral", available at: https://alumni.berkeley.edu/comment/19539 (accessed 13 February 2017).

Meyer, H. (2017), "No Need For Basic Income: Five Policies To Deal With The Threat Of Technological Unemployment", available at: https://www.socialeurope.eu/no-need-basic-income-five-policies-deal-threat-technological-unemployment (accessed 11th December 2017)

Mishel, L., Shierholz, H. and Schmitt, J. (2013), "Don't Blame the Robots. Assessing the Job Polarization Explanation of Growing Wage Inequality", *EPI–CEPR Working Paper*, Economic policy Institute, Washington.

Moniz, A. and Krings, B. (2016), "Robots Working with Humans or Humans Working with Robots? Searching for Social Dimensions in New Human-Robot Interaction in Industry", *Societies*, available at: http://www.mdpi.com/2075-4698/6/3/23/htm (accessed 13 February 2017).

Moretti, E. (2012), *The New Geography of Jobs*, Houghton Mifflin Harcourt Pusblishing Company, New York.

Muñoz-de-Bustillo, R., Grande, R. and Fernández-Macías, E. (2016), "Innovation and Job Quality. An Initial Exploration", *QUINNE Working Paper WP5-1-2016*, QUINNE.EU.

Núñez, C.G., Navaraj, W.T., Polat, E.O. and Dahiya, R. (2017), "Energy-Autonomous, Flexible, and Transparent Tactile Skin", *Advanced Functional Materials*, Vol. 27 No. 18, p. 1606287.

OECD, (2017), *OECD Employment Outlook 2017*, OECD Publishing, Paris.

Oesch, D. (2013), *Occupational Change in Europe: How Technology & Education Transform the Job Structure*, Oxford University Press.

Page, T. (2017), "Digitisation and the future of work: what it means for unions.", available at: http://touchstoneblog.org.uk/2017/02/digitisation-future-work-means-unions/.

Partnership on Artificial Intelligence (2016), *Introduction from the Founding Co-Chair*s, available at: https://www.partnershiponai.org/introduction/ (accessed 22 June 2017).

Peruffo, E., Rodriguez Contreras, R., Molinuevo, D. and Schmidlechner, L. (2017), *Digitisation of Processes – Literature review*, Eurofound working paper, Dublin.

Piasna, A. and Drahokoupil, J. (2017), "Gender inequalities in the new world of work", *Transfer: European Review of Labour and Research*, Vol. 23 No. 3, pp. 313–332.

Planet labor (2015), "Planet Labor, Article nº 9268", 24 September.

Planet labor (2017), "Planet Labor, Article nº 10231", 29 May.

PricewaterhouseCoopers (2017), *Will Robots Steal Our Jobs? The Potential Impact of Automation on the UK and Other Major Economies*, PricewaterhouseCoopers.

Quartz (2017), "Bill Gates: the robot that takes your job should pay taxes", available at: https://qz.com/911968/bill-gates-the-robot-that-takes-your-job-should-pay-taxes/ (accessed 29 August 2017).

Rahbari, E., Frdham, T. and Lehto, T.. (2016), *Technology at Work v. 2.0 The Future Is Not What It Used to Be*, Citigroup.

Rifkin, J. (2005), "The End of Work", *Spiegell Online*, available at: https://pdfs.semanticscholar.org/0a61/d04fa8f5809ffa45897056996567c4986708.pdf (accessed 11 August 2017).

RolandBerger (2014), *Think act - Les classes moyennes face à la transformation digitale*, RolandBerger.

Sheridan, T. (2016), "Human–robot interaction status and challenges", *Human Factors*, Vol. 58, No. 4, pp. 525 – 532.

Smith, A. and Anderson, J. (2014), *AI, Robotics, and the Future of Jobs*, available at: http://www.pewinternet.org/2014/08/06/future-of-jobs/.

Soete L., Kamp K. (1996), "The bit tax: the case for further research", *Science and public policy*, Vol. 23, No.6, pp. 353-360.

Stone, P., Brooks, R., Brynjolfsson, E., Calo, R., Etzioni, O., Hager, G., Hirschberg, J., et al (2016), A*rtificial Intelligence and life in 2030*, Stanford University.

Summers, L. (2017), Robots are wealth creators and taxing them is illogical, *Financial Times*, 5 March.

The Economist (2017), Why taxing robots is not a good idea, February 25.

The Guardian, (2017a), Universal basic income trials being considered in Scotland, January 1.

The Guardian, (2017b), Finland trials basic income for unemployed, January 3.

Valenduc, G. and Vendramin, P. (2017), "Digitalisation, between disruption and evolution", *Transfer: European Review of Labour and Research*, SAGE PublicationsSage UK: London, England, Vol. 23 No. 2, pp. 121–134.

Valsamis, D., Coen, A. de, Vanoeteren, V. and Van der Beken, W. (2015), *Employment and Skills Aspects of the Digital Single Market Strategy. Study for the European Parliament's Committee on Employment and Social Affairs*, Bruxelles.

Varoufakis , Y., (2017), *A tax on robots?* Retrieved from https://www.project-syndicate.org/commentary/bill-gates-tax-on-robots-by-yanis-varoufakis-2017-02

Vasic, M. and Billard, A. (2013), "Safety issues in human-robot interactions", *Robotics and Automation (ICRA), 2013*, pp.197- 204.

West, D.M. (2015), *What Happens If Robots Take the Jobs? The Impact of Emerging Technologies on Employment and Public Policy*, Center for Technology Innovation at Brookings, Washington, DC.

Zhang, Y. (2017), *Would Bill Gates's proposed robot tax help workers?,* Tax Policy Center, Retrieved from http://www.taxpolicycenter.org/taxvox/would-bill-gatess-proposed-robot-tax-help-workers

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