THE JANUS-FACED CHARACTER OF ROBOTICS AND ARTIFICIAL INTELLIGENCE

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THESIS

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ABSTRACT

This survey outlines the discussion on the controversial effects of robots and artificial intelligence as the core drivers responsible for major future disruptions in economies, which is particularly relevant to the future of employment. We essentially focus on labour markets and income generation. We consider the multifaceted implications of these emerging technologies, classifying the negative outcomes under the framework of classical innovation, while enhancing the positive results through the lens of a Neo-Schumpeterian approach. Concerning the influence of robotics on education and society, we analyse the education system and social issues and propose possible policies. This survey provides an overview concerning the current debate, highlighting the arguments of replacement vs. compensation, which we label as the Janus face of robotics and artificial intelligence.

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1. INTRODUCTION

The first Industrial Revolution caused an enormous growth in employment, followed by a substantial decline in production costs and a fast-growing Gross Domestic Product (GDP) per head. Such developments became possible because of the technological progress in agriculture, which allowed increased productivity, while replacing a large fraction of the peasants at the same time. Jenson (1993) observed similar effects during the second Industrial Revolution, which was triggered by the assembly belt and mass production. These industrial revolutions demanded low-skilled workers, because the new technologies led to an exceptional simplification of the tasks. Increasing demand on labour markets, together with the increased productivity, supported employment and growing wages (Frey and Osborne, 2015). Nevertheless, the third Industrial Revolution, starting in the 1970s with the advent of computerisation, was characterized by certain mixed evidences concerning employment. The process of labour substitution was initiated by an increasing application of computers in production, which negatively affected employment, particularly in middle-skilled manufacturing and office occupations. Computers and, somewhat later, the first industrial robots capable of routine work reallocated workers to the manual service occupations, thereby partly displacing labour (Frey and Osborne, 2015). However, we observe from previous revolutions that, depending on the complexity of the emerging industries, the process of reallocation takes time and the struggle of the peasants trying to move into the fabrics can be reflected nowadays in the people striving to switch to other emerging fields (e.g. IT, engineering). One may think that these two struggles are incomparable, but we must keep in mind that during the first or the second industrial revolution, our society was not even approximately developed as it is today. We are becoming a knowledge-based society, where an increasing number of people pursue higher degrees and obtain a greater stock of knowledge. Therefore, we cannot say that history is repeating itself, but it definitely does rhyme (Wittreich, 1987).

Nevertheless, the issue of technological unemployment has to be tackled with particular care, because this time, we face a greater challenge of slow transition, as the emerging industries are highly knowledge-intensive, and it is difficult to skill-up the competences of the low/middle skilled employees, whose replacement is particularly expected with the increase of automation. Previously, computers and robots were perceived more as assistants than as substitutes, while today, with the advent of the fourth Industrial Revolution, the picture is rather different. The accelerating diffusion of robots and artificial intelligence is now widely considered as an alarming threat. How should economic systems deal with the potential massive replacement of existing jobs by robots and what are the implications for the new emerging industries? How do we organize the societies in this twenty-first century of automation and artificial creatures?

Without doubt, these are difficult questions, with many fundamental uncertainties and wicked problems that must be confronted and dealt with.

Not surprisingly, the discussion today is spurred by rather heterogeneous insights from new research in this topic (e.g. Christaller et al., 2001, Frey and Osborne, 2015, Huttenrauch, 2006, Schraft et al., 2004), which highlight the somewhat paradoxical nature of this technological revolution, with its positive as well as negative effects, and which certainly provides a rationale for a new interpretation of Schumpeter´s (1943) idea of *creative destruction*. We refer to a considerable amount of recent research in this field (e.g. Pratt and Gill, 2015; Pew Research Center, 2014; Gorle and Clive, 2013; Acemoglu and Restrepo, 2016; Brynjolfsson and McAfee, 2012), keeping in mind the work of Jeremy Riffkin (1995), who already in 1995 claimed that *the end of work* is approaching and that we cannot prevent it.

Technological unemployment and new emerging fields reflect two different perspectives of technologies strongly debated with labour market economists observing both the negative employment implications (Bartlett, 1984) and the positive implication of emerging employment fields (Stewart, De and Cole, 2015). Through our analysis of the existing literature, we compare the positive and negative effects caused by the introduction of robots and artificial intelligence using two different lenses (perspectives) of economic theories. Namely, we shed new light on what we call the “Janus face” of robotics and artificial intelligence, emphasising on the negative aspect through the static approach of neoclassical economics and the positive one using the dynamic idea of the Neo-Schumpeterian theory.

1.1. PAST AND PRESENT

The idea of robots being used in production is not entirely new. The first industrial robot was invented in the U.S. and patented by Devol in 1954. The first commercialization followed in 1961. However, its wider diffusion took considerable time and many technological improvements were made: After the first application of robots in industry, it took another twelve years until 50 percent of the potential users in relevant industries adopted the new technology (Mansfield, 1988). From this slow diffusion, we should not conclude that the pace of technology adoption remained slow even at the beginning of the twenty-first century. Historical examples show that diffusion technology curves are often sigmoid (Kurzweil and Viking, 1999), which reflects a broader usage of robots and artificial intelligence in many different industries in increasingly shorter time intervals. Modern robots are considered as complex combinatorial technologies, which bundle Moore's Law of exponential performance growth of processors (Newcomb, 2016) and Kurzweil's (2001) accelerating returns. Therefore, together with globalization, decrease in transportation costs due to container shipping and an incredible speed of information processing and transfer, we can expect a massive acceleration of the diffusion of robotic technologies in unprecedented ways.

It is not clear what exactly determines the borderline between traditional production equipment and robots. For our purpose of analysis, we use the definition of Christaller et al. (2001), who defined robots as freely and repeatedly programmable, multifunctional manipulators able to extend the human ability to act, adding that robots could also replace human abilities and tasks. Robots are extremely complex: more degrees of freedom as well as the variety and extent of their forms of behaviour and body distinguish them considerably from other machines (Christaller et al., 2001). We decided to expand the definition because recent developments increasingly characterise robots as completely independent machines that act without any human assistance – robots are increasingly provided with so-called artificial intelligence (AI), which allow for higher degrees of self-adaptation in changing environments. Together with artificial intelligence, many authors predict a penetration of robots, not only in manufacturing, but also in services where freely programmable robots may be used to carry out partially or fully autonomous services (Maleri, 1997, Schraft et al., 2004).

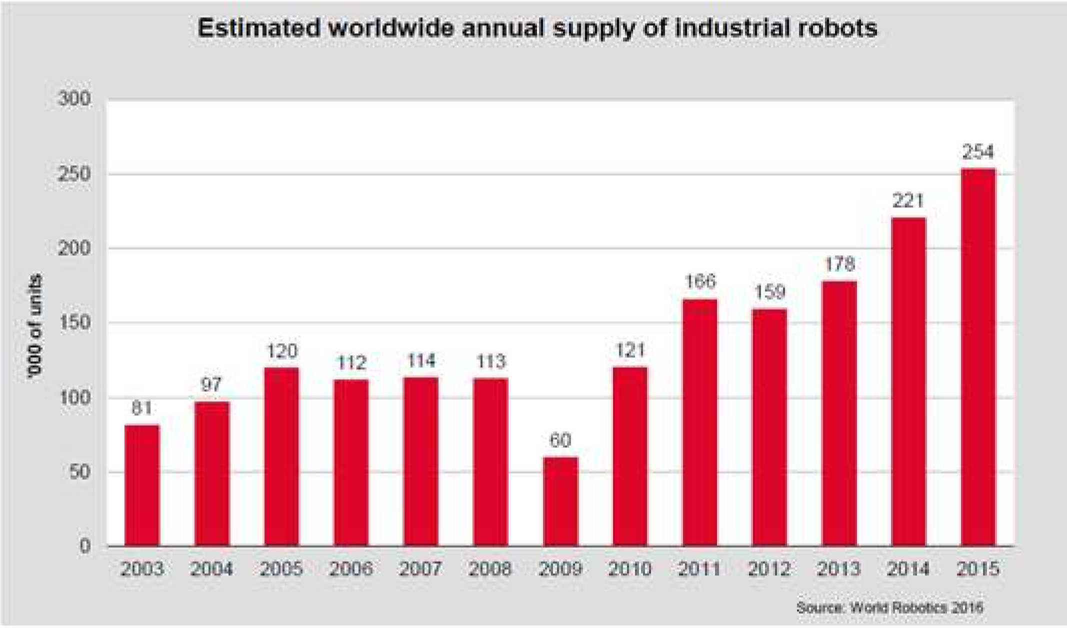


Figure 1: Diffusion of industrial robots between 2003 and 2015

From an empirical point of view, it is interesting to observe the vast number of robots already in use. To illustrate the increasing importance of robots, Figure 1 displays the worldwide numbers of newly installed robots in industry. It is not surprising that the topic of robotics and artificial intelligence is becoming increasingly relevant, as in 2015, robot sales increased by 15 percent to 253,748 units which is, by far, the highest level ever recorded in one year.

According to the Executive Summary of World Robotics for 2016, the main driver of the growth of robotics in 2015 was industry, with an increase of 33 percent as compared to 2014. Comparing the diffusion internationally, Asia is the world's strongest growth market with 160,600 units sold in 2015.This represents a rise of 19 percent as compared to the previous year. Europe takes the second rank with an industrial robot sales increase of 10 percent, representing 50,100 units. The third place is reserved for the U.S., with an increase of 17 percent.

Figure 2 displays the sectorial differences in robotic applications. Car manufacturing leads the investment in robotics. Between 2010 and 2014, there was a considerable increase of investments in industrial robots worldwide. It is also noticeable that demand for industrial robots increased remarkably in other industries too, which underlines the idea of robots as a general-purpose technology (Lipsey and Carlaw, 2005).

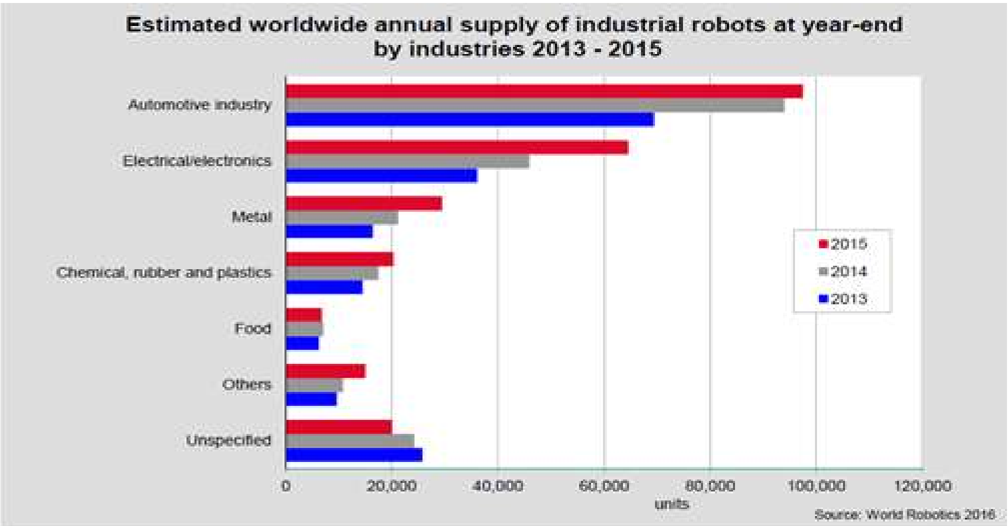


Figure 2: Annual supply of industrial robots between 2013 and 2015

The remarkable increase of robot installations might indicate labour substitution, at least in the short-term. From a long-term perspective, it may also open a spectrum of new occupations and jobs (Graetz and Michaels, 2015; Riffkin, 1995). Current literature is highly divided on the final effects of labour substitution and robots and AI introduction (Riffkin, 1995; Murnane 2005; Stweart, De and Cole, 2015). While the pragmatic and dystopian scholars stress the negative effects of technological advances, imaginaries and evolutionary economists point to the positive aspects of robotics and AI. It is interesting to note that these two different perspectives lead to contrasting predictions of our future. In the following chapters, we will discuss and weight the positive and negative aspects of robotics and AI technologies using the lens of neoclassical and evolutionary economics. Moreover, we tackle the issues of the current educational framework and the question the final effects of robotics and AI on societies. We summarise the analysis proposing some policies and conclude the paper with the final remarks and the outlook for future research.

2. ROBOTICS AND ARTIFICIAL INTELLIGENCE – A JANUS-FACED TECHNOLOGY

Ever since the times of the ancient Roman civilization, the two-faced Roman god Janus has had different meanings. He frequently symbolizes change and transition from the past to the future, from one condition to another, or from one vision to another. He also represents time, because he sees the past with one of his faces and the future with the other (Bernard, 1925). Apart from its ancient symbolism, this expression is widely used to describe good and bad or "the double face". Robotics and AI are technologies with the double face. From the neoclassical perspective, using the statistical figures, we see the face of Janus characterized with technological unemployment and job polarization. Instead, the good side is visible from evolutionary perspective, which emphasize positive features of these technologies, as well as the emerging sector and growth of variety. Both aspects are somehow narrow and concentred on only one of the sides. While mainstream economics uses the neoclassical school of thought as a dominant paradigm reflecting the "inadequate orthodox ontology of innovation"(Courvisanos, 2007), evolutionary economics ignore the destructive part of the innovative creation processes (Buenstorf et al. 2013). In order to assess the comprehensive overview, we emphasize and discuss the Janus-faced character using both lens - neoclassical and evolutionary innovation approach.

2.1. TECHNOLOGICAL SKEPTICISM IS NOT NEW

Transition processes are difficult due to the uncertain character often related to the insecurity and risk that comes along with it. From the very beginning of industrialization, innovations were frequently illustrated as dangerous for people and their employment. The "Luddite" riots from 1811 to 1816, at a time when mechanization was entering the textile industry, reflected this fear. However, neither the Crown nor the guilds had the power to halt technological progress. The Roman writer, Pliny the Elder, nicely illustrated this with a story of the Roman Emperor

Tiberius. An inventor who discovered a way of manufacturing unbreakable glass approached the emperor hoping for a reward. Tiberius, who feared the devastating consequences of this invention for glass manufacturing, condemned the man to death (Acemoglu and Robinson, 2012).

Although inventors are less endangered today, the social concern about drastic changes induced by new technologies cannot be overseen. John Maynard Keynes (1930) first coined the notion of technological unemployment, where he observed the faster discovery of means that economise the use of labour rather than initiate compensating mechanisms which create new jobs. In capitalism, where private businesses lead by productivity and cost efficiency targets, continuous attempts to reduce labour costs (see Marx, 1867) may cause great harm to the labour markets.

Particularly with the introduction of robotics and artificial intelligence, the economising means are reaching their unprecedented level, thus becoming a great burden for the society and its people. As recently noted by the CEO of the World Bank, "The world has never been wealthier, yet there has never been so much anxiety over the future of work" (Georgieva, 2017).

Dexter Kimball (1933) notes that, "For the first time a new and sharp question is raised concerning our manufacturing methods and equipment, and the fear is expressed that our industrial equipment is so efficient that permanent overproduction ... has occurred and that consequently technological unemployment has become a permanent factor." Historical examples of this very situation spans from the mechanization in agriculture, which drastically decreased agricultural employment to the computerization in administration, which has already replaced millions of clerks in banks and insurance companies (Riffkin, 1995).

However, not everyone sees displacement as the long-term negative effect. According to John Bates Clark, founder of the American Economic Association, “the well-being of workers requires that progress should go on, and it cannot do so without causing temporary displacement of labourers" (Clark, 1907). The displacement of workers and introduction of different technologies occurred in a span of more than 100 years and, in most of the instances, displaced workers found jobs elsewhere. Therefore, there is much reason to think that such reallocation of employees will happen again. It is a question of time, resources, and policies on how to deal with the new environment and technological novelties. The eventual solution, beneficial for the entire society, will simply emerge from our efforts and attempts to compensate for negative and embrace positive effects that robotics and AI can bring to our lives and societies.

In this paper, we argue that perceiving automation from the statistical perspective of historical data and the purview of the current tendencies may lead us into the direction of the negative side of robotics and artificial intelligence. However, if we take a more dynamic approach into account and allow for uncertainty and heterogeneity to enter the scene, the results may be quite different and luckily positive. The foundation of such a contraversive analysis is rooted in two opposing literature streams. Namely, the neoclassical approach, which sees the innovation through the prism of situative determinism with well-structured data to analyse and evolutionary approach, with economic behaviourism characteristics focusing on the dynamically changing environment. In what follows we present the current statistics and tendencies created by the introduction of robotics and AI and then we focus on the new emerging sectors and beneficial aspects of these technologies.

3. NEGATIVE LENS OF ROBOTICS AND AI

Neoclassical economics is a theory oriented towards rational individuals, where the competition is based on price mechanisms, increasing productivity and quality (see Arrow 1962) and where time is not important. In the sphere of innovation, this approach provides a narrow overview of different sectors and industries, without considering the broad spectrum of innovation drivers and their effects. Innovation, in particular, is aimed at increasing efficiency. Theoretically, this leads to the shift of the production function, where technology is considered as an exogenous factor influencing economic growth.

If we observe robotics and artificial intelligence through such a static perspective and take into account only the short-term measurements, we notice that the latest developments in these spheres emphasise the effects of a decreasing labour demand – the dark Janus face. As a matter of fact, the replacement is happening at all the fronts, and although human work involves some cognitive processing of information, by exploiting big data and applying sophisticated algorithms, the robots are increasingly being able to perform even highly complex activities (Murnane, 2005). For instance, agricultural software assists farmers and computerized "expert systems" collect data on weather changes. The car industry, as the leader in application of robotics and AI, has already witnessed dramatic breakthroughs in re-engineering and technology displacement.

Figure 3: 19 Economies average labour share estimate

Blue-collar workers in this industry represent the group which is most vulnerable to fall prey to the increased use of robots, since their skills and abilities are easily programmable and replaceable by robots. In order to decrease the costs, the process of replacement may go even further, as the new generation of "smart" robots, armed with flexibility and greater intelligence, are making their way into the factories (Riffkin, 1995).

There are many other related industries (see Riffkin, 1995) using this technological replacement as the core driver for achieving cost efficiency, which is causing further elimination of more jobs. Indeed, such increase in efficiency is also emphasized in the literature of neoclassical economics as the driving innovation force that enable producers to exploit the technologies and further decrease costs or increase quality.

Therefore, neglecting the growth in variety, the worries and dark predictions of the future are somewhat based on the results of the current employment rates. The workforce participation rate in the U.S. recently fell below 64 percent. To depict the gravity of the situation, this level of participation rate was last seen in 1983, but at that time, women were not included as a part of the labour market statistics (Brynjolfsson and McAfee, 2012).

Economies of other countries also demonstrate mostly similar results. Figure 3 shows a GDP-weighted average of the labour share for 19 advanced economies[1], using AMECO data. On an average, labour shares declined from around 61 percent in the mid-1970s to 54 percent in 2014. Another troublesome trend of declining GDP related to labour is also widely present all over the world. The study of the Global Decline of the Labour Share (Karabarbounis and Neiman, 2013) found that 42 out of 59 countries experienced a fall in the share of their GDP related to labour, and this trend is even present in emerging economies like China. According to this study, the explanation of this decline is to be found in the decrease of the relative prices of investment goods. The researchers conclude that advances in computer technologies, leading companies to substitute labour with capital, drove such a decline in investment good prices. However, the exact correlation is not found and they suggest that the decline in the relative price of investments explains only the half of the decline in the global labour share.

Keeping in mind the dynamics of technological progress, the introduction of new jobs and the potential new demand for labour are promising observations. However, the great challenge here is that new jobs are definitely not relevant for everyone, especially for the labour force equipped with skills for cognitive routines or manual jobs. Following the idea of the Faustian aspect (Blok and Lemmens, 2015) of

[1] The 19 advanced economies included are the US, the UK, Austria, Belgium, Denmark, France, Italy, Netherlands, Norway, Sweden, Canada, Japan, Finland, Greece, Ireland, Portugal, Spain, Australia and Germany.

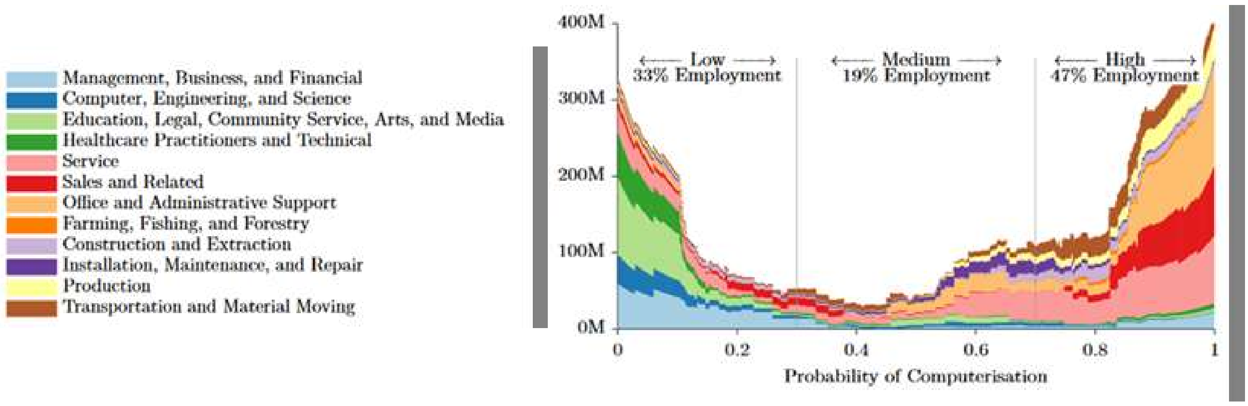
innovation, we notice that automation may be the kind of technology benefiting a few at the expense of many (Soete, 2013). The findings of Lin (2011) show that only 8.2 percent of the workers in the United States were employed in new types of jobs in 1990. This figure further decreased over time and sharply fell to 4.4 percent in 2000. Moreover, Berger and Frey (2015) estimated that less than 0.5 percent of workers in the United States are today employed in the industries created in the 2000s.

Limiting the sight only to the agricultural industry, it is evident that within a span of two centuries, the labour share in the U.S. saw a sharp decline from 90 percent in 1800 to only two percent in 2000 (Dimitri, Effland and Conklin, 2005) and the decreasing trend is expected to continue. The milking robot from Lely, for example, autonomously adjusts the feeding and milking process to optimize the milk production for each cow. Some studies suggest that it is only a matter of time before humans are removed altogether from agricultural farming (OECD, 2016). However, over time, a well-functioning economy should be able to adjust to the new consumption paths and changes in labour markets. As workers left farms over the course of two centuries, new jobs were created in other sectors, and whole new industries emerged to employ them.

3.1. WHICH JOBS ARE AFFECTED?

Robotics and AI represent technologies tempted to bring radical change to labour markets and our societies. Those observing current tendencies and the path of technological advancements point to the jobs, which might be displaced in the future. Acemoglu and Restrepo (2016) introduced the task-based model, where automation always reduces the share of labour in the national income as well as in employment, while the creation of new complex tasks, where the labour tends to have comparative advantage, always increases wages, employment, and the share of labour. The final implication of their model identifies a new source of inefficiency that pushes towards too much automation and too few new tasks being created.

This inefficiency arises because automation enables firms to reduce wage costs, reflecting the “destructive creation” nature of an innovation, which could benefit a few at the expense of many (Soete, 2013). In cases where wage costs can be transferred to capital rents, they predict more automation than desired, and as a result, the technology may become inefficiently biased towards replacing labour.



Source: Frey and Osborne, 2017

Figure 4: The distribution of employment over the probability of computerization

When it comes to the different occupations that are likely to be displaced, we refer to the evidence provided by Frey and Osborne (2017). They distinguished between high, medium, and low risk occupations, depending on their probability of computerisation. It is remarkable to notice that according to their estimates, 47 percent of the total U.S. employment force is in the high-risk category, where occupations are potentially automatable over some unspecified number of years. Figure 4 displays that most employees in administration, transportation, and logistics as well as labour in production are likely to be substituted by machines.

The trend of replacement is likely to continue, as industrial robots are becoming increasingly able to perform a wider scope of non-routine manual tasks. Moreover, a considerable share of the employment in services, sales, and construction exhibits high probabilities of computerisation (Frey and Osborne, 2017).

These findings are largely in line with the recent technological developments. For instance, the market for personal and household service robots is growing annually by about 20 percent (MGI, 2013) and the global sales revenue is forecasted to grow by 23.5 percent per annum between the 2015–2020 period (GMD, 2015). It seems counterintuitive that sales occupations, which are likely to require a high degree of social intelligence, will be subject to a wave of computerisation, but the model by Frey and Osborne (2017) include, for example, cashiers, counter and rental clerks, and telemarketers, which do not necessarily require these skills.

However, increasing productivity is one of the core prerequisites for the creation of new resources used in research and innovation, which will allow for a further increase in variety and efficiency. Such an increase is the essence of economic development leading to the creation of new industries and sectors because “variety is in itself a powerful source of innovation” (Saviotti and Pyka, 2004). Such a transition of resources also happened during the process of industrialization, because the growth in agricultural productivity created the resources required for initiating industrialization (Kuznets, 1965).

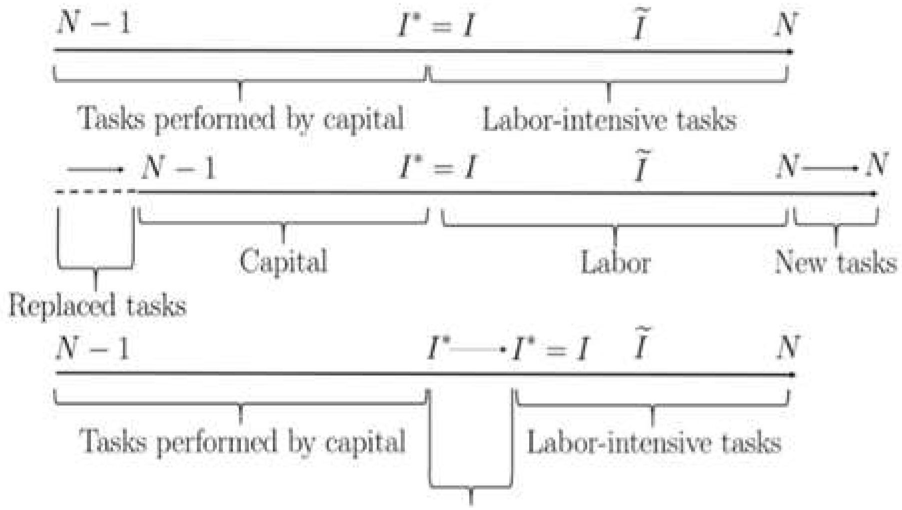
3.2. JOB POLARIZATION

As discussed in the previous chapter, skill-biased technological change is likely to increase the relative demand for high- and low-skilled labour while reducing or, in some cases, eliminating the demand for middle-skilled labour. From Figure 4, we notice that the job occupation most susceptible to automation is in the sector of administration and office support. But we should ask ourselves if this should be considered as a threat, because it is well known that these jobs are considered as routinized and lousy. Anyhow, such a phenomenon of hollowing-out the middle-skilled employees is known as job polarization (Goos and Manning, 2007). This phenomenon is observed when jobs, requiring a moderate level of skill, disappear relative to those at the bottom and the top.

Empirically, job polarization is reflected by a secular decline of middle-income jobs, accompanied by a structural shift in the labour market, with workers reallocating to low-income jobs that are less susceptible to automation. Consequently, income inequalities increase (Autor and Dorn, 2013; Goos et al., 2007). However, the automation and introduction of new complex tasks may have different effects in the long term. The task-based model of Acemoglu and Restrepo (2016) observed that new tasks are more complex and their creation may favour high-skilled workers. Figure 7 describes the introduction of new, complex tasks where high-skilled workers have a comparative advantage. Short-run comparative statics imply that automation, by squeezing out tasks previously performed by low-skilled labour, increases inequality between the two types of skills.

However, automation and introduction of the new complex tasks have different implications for the employees. In the medium run, the creation of new complex tasks tends to standardize, which raises the productivity of the low-skilled workers. Therefore, according to Acemoglu and Restrepo (2016), automation increases inequality in both short and medium run, while the creation of new tasks induces low-skilled workers to “skill up” and, thus, gain from the capital.

Therefore, if we take a narrow perspective of classical economics and neglect time, isolating automation from the introduction of the new complex tasks, we observe high rates of job polarization. But if we allow for an extensive analysis and suppose that the automation will lead to the introduction of new complex tasks (which we will discuss in the next chapter), the increased complexity will raise the productivity of low and middle skilled employees, allowing them to benefit from new knowledge and higher skills.



Source: Acemoglu and Restrepo, 2016

Figure 5: Introducing new complex tasks and automating existing tasks

Anyhow, this process of skilling up the employees is not an easy task and poses a great challenge, not only for private institutions, but also for governments and civil societies. As Frey and Osborne (2015) dissent and argue, it may be possible for workers to quickly “skill down”, but it may not be as easy for them to “skill up” to take higher-skilled jobs and acquire competence in those complex tasks.

Negative aspects of robotics and artificial intelligence introduced so far represent the result of an approach that takes into account only a particular industry or a sector, neglecting the time, growth in variety and long-term horizon. In order to assess more realistic impact of these technologies, we have to broaden our spectrum and allow for the dynamics of economy to enter the scene. This has been done in the following chapter, using the flavour of Schumpeters´ (1912) ideas who claimed that the innovation is a“process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one.”.

4. POSITIVE LENS OF ROBOTICS AND AI

Neo-Schumpeterian Economics is a theory concerned with all the facets of open and uncertain developments in socio-economic systems (Hanusch and Pyka, 2007). Schumpeter is considered as the godfather of the innovation theory, because he was one of the first authors who stressed on the importance of innovation and described economic development as the disruption of the regular circular flow caused by the introduction of novelties (Schumpeter, 1912). Using this sense and understanding of economics and technological disruption, we observe that the introduction of robotics and artificial intelligence may have an extremely positive impact on labour markets as well as on the society.

First, let us have a look at how these technologies have helped us. Generally, the number of routine jobs decreased the most as a result of automation (OECD, 2016), and in most of the cases, these jobs are considered as lousy and non-stimulating (Goos and Manning, 2007). Moreover, robots are capable of replacing humans in doing heavy, dangerous, and monotonous tasks. A study by Stewart, De and Cole (2015) observed that technological change has led to a reduction in jobs requiring physical strength in England and Wales over the last 150 years. The share of manual labour dropped from 24 percent of all employment in 1871 to eight percent in 2011. The most recent artificial intelligence machines are supposed to prevent us from headaches, heavy and lousy jobs. McAffee and Brynjolfsson (2012) provided the anecdote of Bill Herr, a lawyer, who complained about the increasing number of documents to be read saying, “People get bored, people get headaches. Computers do not.” At the same time, we observe a shift to jobs requiring care and empathy from one percent in 1871 to 12 percent in 2011 (Stewart, De and Cole, 2015).

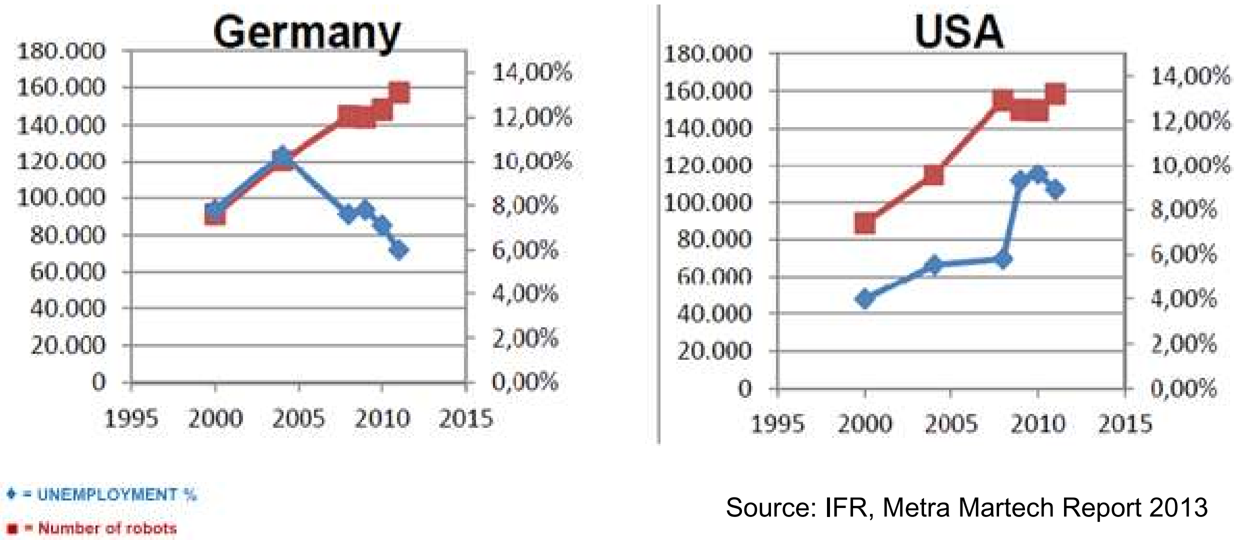
Therefore, not only are robotics and artificial intelligence eliminating our heavy and boring work, but they are also creating new jobs in more sensitive and stimulating environments, as well as in sectors directly related to these new technologies.

Without a doubt, the full potential of robots has neither been explored nor been exploited thus far. Usually, the final application of a new technology is rather different compared to the inventors’ ideas. Therefore, the introduction of robotics and artificial intelligence, in the long term, may impact our society and institutions in a different fashion from the one we perceive today. Within the ambit of technological development itself, many application ideas have been tested with countless failures and dead ends (Stweart, De and Cole, 2015). Accordingly, we cannot envision how robots are going to be used in the future and what will be its ultimate outcome in terms of employment and labour markets.

The importance of the sole perspective of robotics and artificial intelligence is evident in the study by Gorle and Clive (2013), where they claim that the introduction of robotics and artificial intelligence contributes positively to employment and facilitates adding value to work. Their recent report reveals that the continuous influx of robots and artificial intelligence will truly contribute to the overall rise in employment, because of the creation of many new jobs in distribution, services, and new manufacturing applications. Figure 6 partly illustrates their argument: While the number of robots in Germany and the U.S. is steadily increasing since the end of the 1990s, unemployment rates had started to decrease in Germany around 2004. In the U.S., this effect is less visible and is super imposed by the devastating effects of the recent financial crisis in labour markets.

Transition to new technologies and adaptation to new environments is complex, as many different dynamics interfere with each other. What will be the outcome of increasing automation and what will be its overall impact on labour markets?

The negative consequences may only be the outcome for the immediate transition – skills, job descriptions, and the market applications still have a scope to be explored and then developed. Keeping in mind the comprehensive understanding of economic development (Hanusch and Pyka, 2007) and following the Metra Martech Report (2013), new products and services based on robots will create enormous economic opportunities that will not only affect both the established industries and entrepreneurial activities but also the financial markets and the public sector. The expansion of the existing sectors is one resultant effect. More importantly, particularly in highly developed and knowledge-based economies, the number of small and medium-sized enterprises (SME) will expand, with an increasing application of robotics in new fields.



Source: IFR, Metra Martech Report 2013

Figure 6: Comparison of the unemployment rate and the number of robots

The enormous potential application of robotics in SMEs will initiate the emergence of new industries (Grebel et al., 2003), which will eventually affect consumers, who will gradually become aware of the new commodities and services on offer (Hanusch and Pyka, 2007). These developments lead to an increasing demand for new and highly qualified employees. As claimed by Gorle and Clive (2013) a rise in employment might lead to an increasing demand for services and the creation of completely new products and markets, often related to electronic communication and technology, which require highly educated labor. A change in composition, leading to a growth in variety, can be a form of compensation for the potential displacement of labour and of the other resources we discussed about in the previous chapter. Therefore, if the variety grows there has to be more creation than the destruction. (Saviotti and Pyka, 2004).

4.1. PROSPECTIVE INDUSTRIES AND OCCUPATIONS

The previously mentioned comprehensive economic approach takes into account all realms relevant to an improved understanding of the economic processes under investigation (e.g. industry, public sector, and financial markets). In cases where the different realms are in close relation, mutually influencing each other, which is very likely the case for economic development (Hanusch and Pyka, 2007), we must allow for interdependencies to enter the scene. For the sake of this analysis, we concentrate on the inter-relationships among different industry sectors. In a world of network relationships (see Gulati et al., 2000; Uzzi, 1997), affected industries may not only influence its related ones but could also lead to the emergence of new sectors and job titles.

In relation to the studies of Gorle and Clive (2013), using statistical data, Stewart, De and Cole (2015) evidently claim that technological progress in the UK, contrary to the neoclassical reasoning, continues to create new jobs.

They identified four mechanisms that influence employment. Through direct effects, technology can be substituted for labour (e.g. manufacturing, agriculture). But at the same time, the new technology generating sectors expand rapidly and employ more labour (e.g. software engineering, scientific research). Moreover, indirectly, technology generates new labour demand in complementary sectors (e.g. health care, knowledge-intensive business services) and lowers costs of production and prices which enable consumers to shift their spending to more discretionary goods and services (e.g. gym, entertainment). These mechanisms depict the idea of more creation than destruction, which, as previously stated, is a prerequisite for further economic development.

Being convinced that the current discourse is biased towards the job-destroying effects of technological change, the authors analysed the employment data covering a period of 150 years from the census of England and Wales and the Labor Force Survey. Table 1 provides an overview of creative destruction in the UK labour force since 1992, where it is evident that there is a dominant trend of diminishing employment in agriculture and manufacturing which, however, is more than offset by the rapid growth in caring, creative, technology, and business service sectors. As the table shows, routine jobs, both cognitive and manual, have suffered the most. This is because technology can readily substitute manufacturing and paperwork.

At the same time, the new technology is highly complementary to cognitive, non-routine tasks, and in these fields, the employment growth is strong (Stewart, De and Cole, 2015). These observations have largely been confined to skilled workers. Thus, cities, regions, and nations with a pool of skilled workers have benefited disproportionally from the recent technological changes (Berger and Frey, 2015)

However, introduction of robotics and artificial intelligence does not have the same effect in different markets and geographical areas. New fields of knowledge emerging and new industries coming into the scene reflect differently at the macro-level. We not only observe diverging growth rates between different countries (Saviotti and Pyka, 2004), but also that the final technological impact differs a lot.

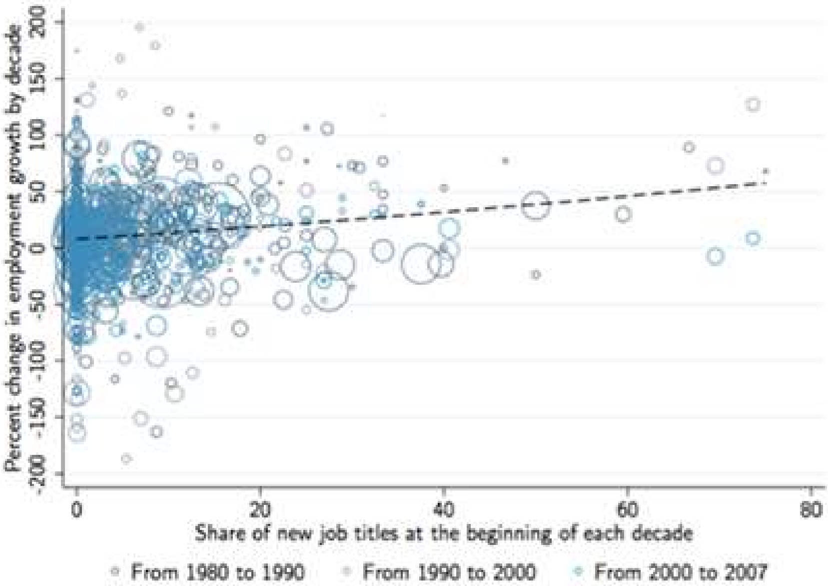
In particular, according to the most recent findings of Graetz and Michales (2017), a pronounced distinction can be made between the U.S. and the rest of the developed world. Jaimovich and Siu (2014) proposed an explanation for the "jobless" recoveries in the U.S. being rooted in the observed technological change. For the rest of the developed world, these results seem quite implausible. Using data on economic recoveries from 1970 to 2011, Graetz and Michaels (2017) found that although GDP recovered more slowly after the recent recessions, employment did not. Industries in other countries, characterized by routine tasks and exposed to automation, did not experience such slow employment recoveries. Even the middle-skilled employment group did not recover after recent recessions. Therefore, empirical evidence suggests that technology does not cause jobless recoveries in developed countries outside the United States.

Occupations	Employment in 1992	Employment in 2014	Change since 1992
Total employment	24,746,881	30,537,415	23%
Nursing auxilliaries and assistants	29,743	300,201	909%
Teaching and educational support assistants	72,320	491,669	580%
Management consultants and business analysts	40,458	188,081	365%
Information technology managers and above	110,946	327,272	195%
Welfare, housing, youth and community workers	82,921	234,462	183%
Care workers and home carers	296,029	792,003	168%
Actors, dancers, entertainment presenters, producers and directors	47,764	122,229	156%
Financial managers and directors	88,877	205,857	132%
Footwear and leather working trades	40,715	7,528	-82%
Weavers and knitters	24,009	4,961	-79%
Metal making and treating process operatives	39,950	12,098	-70%
Typists and related keyboard occupations	123,048	52,580	-57%
Company secretaries	90,476	43,181	-52%
Energy plant operatives	19,823	9,652	-51%
Farm workers	135,817	68,164	-50%
Metal machining setters and setter-operators	89,713	49,861	-44%

Source: Labour Force Survey, authors' calculations

Table 1: Fastest growing and fastest shrinking occupations since 1992[2]

Even if the portion of the "jobless" recovery in the United States may be explained as a result of the technological unemployment, new job titles within each occupation in the United States steadily grew, in which workers performed newer tasks than those employed in jobs that are more traditional (Lin, 2011). For instance, in 1990, radiology technician, and in 1980, management analyst were new job titles. In 2000, about 70 percent of the workers employed as computer software developers held new job titles.



Source: Acemoglu and Restrepo, 2016

Figure 7: Employment growth against the share of new job titles

[2] Does not include occupations for which LFS sample sizes are too low for reliable employment estimate or those that have been subsumed into significantly larger occupations due to changes in classification.

Figure 7 shows that for each decade since 1980, employment growth has been greater in occupations with newer job titles. The regression line shows that occupations with 10 percentage points – newer job titles at the beginning of each decade – grew 5.05 percent faster over the next 10 years. From 1980 to 2007, the total employment in the United States grew by 17.5 percent. About half (8.84 percent) of this growth is explained by the additional employment growth in occupations with new job titles, relative to the benchmark category of no new job titles (Acemoglu and Restrepo, 2016). Thus, "below the superficial notion that automation automatically creates unemployment, the more likely one is to conclude that it does not" (Bartlett, 1984).

4.2. BENEFITS OF ROBOTICS AND ARTIFICIAL INTELLIGENCE

The kind of jobs and occupations which might remain or emerge include low-risk jobs that are intensive in social and creative skills or require a knowledge of human heuristics – jobs involving the development of novel ideas and artefacts, jobs that are innovative, thoughtful, and interesting.

Computers do not have the human ability to engage in complex social interactions, such as negotiating and persuading, and while they can now solve even the most complicated problems, they are not good at developing original ideas (Frey and Osborne, 2015).

As previously mentioned, technology is changing our working life, and when it comes to the workload, most of the recent technological advances turn out to be beneficial and advantageous. Many technologies complement our work rather than substituting it; they reduce the burden and save time for other activities. For instance, robots can be used to assist patients and elderly people in many activities (Frey and Osborne, 2015). The nurses, who had previously been performing all these activities, will have more time to dedicate and personally socialize with patients.

Moreover, according to the US Bureau of Labour Statistics occupational projections, occupations such as computer network specialists and web developers are expected to add a remarkable number of 94,200 jobs before 2022. Furthermore, the increasing use of advanced ICTs, such as data analytics, has raised the demand for new types of skills. In the U.S., since 1999, occupations for those with advanced ICT skills have been among those with the fastest growth in relative wages, also suggesting (combined with other evidence) a possible shortage of such skills (OECD, 2016). We will later discuss the current shortage of skills and the necessity to change the education system in order to meet the new skill requirements. It is also important to mention that cognitive skills are especially rewarded across the labour markets of all 22 OECD economies. In countries like Sweden, Norway, and the Czech Republic, the premium is below 13 percent, while countries like the UK, Ireland, Germany, and Spain exhibit premiums above 20 percent (Autor, 2014).

Humanoid robots are also quite primitive, with poor fine motor skills and a habit of falling down stairs. Therefore, it does not appear that gardeners and restaurant or kitchen helpers are in danger of being replaced by machines in due course (McAffee and Brynjolfsson, 2012). Thus, highly skilled employees and workers with particular cognitive and social skills, as well as the workers in the service sector are likely to benefit from such an increase. This implicates the Janus of robotics in a positive aspect.

Furthermore, the digital revolution requires less capital investment where innovators and entrepreneurs, who could also be private individuals or consumers (for democratization of innovation, see e.g. Von Hippel, 2005), are likely to become the main beneficiaries (Frey and Osborne, 2015).

In the field of consumption, artificial intelligence and robotics already have had an enormous impact. The observed increase in the entire field of service robots, strongly driven by miniaturization, cost digression, and increased computing capacity, allows for the implementation of hardware and software components in the mechanical parts of robots (Ott, 2012). For instance, remote health monitoring decreases the need for staying in hospitals, but it may also allow some patients to stay at home, with their health conditions monitored by machine-learning algorithms (Frey and Osborne, 2015).

Due to the fundamental uncertainty of innovation processes and its final effects, the benefits of robotics and artificial intelligence may not be overseen in the span of a decade or two. Anyhow, in this process of creative destruction, we will hopefully observe more creation than destruction, coupled with a growing diversity (Hanusch and Pyka, 2007). It is not rational to assume that all human skills will become obsolete. In fact, even in an age of incredibly powerful and capable digital technologies and robots, some human skills are more valuable than ever. Even though other skills have become worthless and people who hold them can offer little to their employers (Brynjolfsson and McAfee, 2012), the process of transition should happen, and it is only a question of time before these people find themselves in different industries and occupations.

5. EFFECTS ON INCOME DEVELOPMENT AND DISTRIBUTION

The final impact of technology depends, among other things, on the relation between substitution and complementarity. The historical wave of re-engineering and automation was only the beginning of a technological transformation. This wave accelerated productivity development considerably and made an increasing number of workers redundant and irrelevant in the global economy (Riffkin, 1995). Additional technology utilization and appliances promised even further productivity increase. For instance, in the U.S., output and productivity in firms adopting data-driven decision making are five to six percent higher than expected (Brynjolfsson, Hitt and Kim, 2011). Autonomous drill rigs can increase productivity by 30 to 60 percent (Citigroup, 2015) while warehouses equipped with robots made by Kiva Systems can handle four times as many orders as un-automated warehouses (Rotman, 2013).

The potential economic benefits of new digital technologies are large, and the available estimates suggest that the Internet of Things (IoT) could contribute $10 trillion to $15 trillion to the global GDP over the next 20 years (Evans and Anninziata, 2012). Furthermore, global manufacturing labour costs today annually amounts to $6 trillion and further adaptation of automation could represent considerable cost savings. According to McKinsey, in developed countries, across occupations such as manufacturing, packaging, construction, maintenance, and agriculture, 15–25 percent of the tasks of industrial workers could be automated cost-effectively.

On the other hand, in developing countries, five to 15 percent of manufacturing workers' tasks could be automated across relevant occupations by 2025 (Frey and Osborne, 2015). These are only some of the examples where technology vastly contributes to an increasing productivity.

Simultaneously, these technologies are decreasing the relative importance of human labour. As a result, the owners of capital equipment can capture a larger share of the overall income. Therefore, as technology replaces labour, the share of income earned by the equipment owners' rise, as compared to labour income (McAffee and Brynjolfsson, 2012).

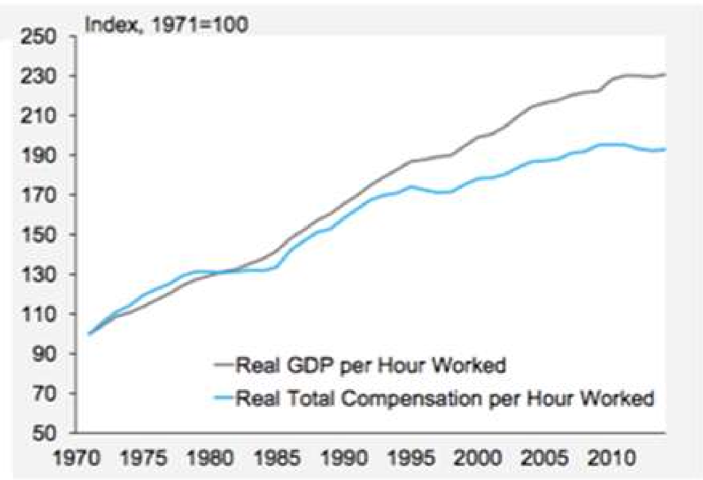
However, such microeconomic turbulence is a requirement for stable macroeconomic growth path (Hanusch and Pyka, 2007) and the long-term effects promise different results. According to Basu, Fernald, and Kimball (2006), in the short-run, employment might decrease, following productivity-enhancing technology shocks. Employment will start to grow again in the medium term. There is evidence that productivity-raising technology shocks reduce unemployment only for several years (Trehan, 2003). Affirming this, since the last recession ended, real spending on equipment and software has soared by 26 percent, while payrolls have remained essentially flat (McAffee and Brynjolfsson, 2012).

When it comes to the wages, the results somewhat vary across different geographical regions. For instance, the U.S. has seen wages accelerate at the high end of the skill distribution quicker than at the low end. The same is true for Canada, Germany, and Australia. In contrast, Japan and the U.K. have seen wages both at the bottom and the top of the skill distribution to rise roughly in tandem, consistent with the job polarization story. In other advanced economies, such as Spain and France, wages at the bottom of the skill distribution have actually accelerated quicker than at the top (Frey and Osborne, 2015).

Most of these productivity enchancing technologies contribute to the enormous value creation in the world. How is it possible that people are sceptical concerning their future, when more value is being created than ever before? The analysis of technology is apparently full of paradoxes. Piketty and Ganser (2014) argue that the labour's share in the GDP tends to fall when the rate of return on capital is greater than the rate of economic growth. Nevertheless, why do wages fail to grow in tandem with productivity? Frey and Osborne (2015) provided this explanation by referring to the changing nature of innovation. Technology raises productivity and should also, consequently, boost wages. But when new technologies replace labour with capital, productivity growth will simply enhance the share of capital income, and thus the concentration of wealth rather than the wages.

Anyhow, the relationship between wealth and income inequality across countries is far from intuitive. In some countries like the U.S., both are high, whereas South Korea exhibits both low wealth and income inequality.

Countries like Switzerland and Denmark have relatively low levels of income inequality, but also the highest levels of wealth in the OECD (Frey and Osborne, 2015). The reason for this concentration of wealth is in line with the theory of economic growth. Economic growth is not triggered by hard work but by smart work (Solow, 1956). New technologies and new techniques of production create more value without increasing labour, capital, and other resources used. For instance, in the period between 1980 and 2000, each extra pound of the UK GDP growth was accompanied by around 90 pence of median wage growth. In the period between 2000 to 2007, this number declined down to 43 pence (Pessoa and Van Reenen, 2013).



Source: European Commission, Citi Research

Figure 8: Advanced economy average productivity gap

This trend is likely to continue and, according to the recent report from the Resolution Foundation (2013), living standards for many low-to-middle income households in the UK are likely to be lower by 2020 than they were in 2008.

Figure 8 shows a GDP-weighted average estimate of the so-called productivity gap for 16 advanced economies. We observe a decoupling of productivity and wage developments. The widening gap between them is due to an increased usage of labour-substituting capital (McAffee and Brynjolfsson, 2012).

We previously argued that robotics and AI are leading to the emergence of new sectors as well, opening new working places and sectors. However, this transition process is slow and the reason why wages fail to keep pace with productivity is that most workers are unable to adapt to this increasing pace of technological change (Frey and Osborne, 2015; McAffee and Brynjolfsson, 2012). On the other hand, owners of capital are able to use technological advances to their full extent, delivering more value with the same or even lower costs. As wealth does not disappear from the society, (McAffee and Brynjolfsson, 2012) the winners (capital owners) certainly see the good side of the Janus face.

However, even if some scholars claim that the losers compose the majority, 90 percent or more, of the population (McAffee and Brynjolfsson, 2012) we have to take into account the dynamics and time horizon when observing these shifts of the value. If we perceive economic development as the interaction between creation and destruction, including the variety, growth is going to definitely lead to more creation than destruction and even old sectors will be transformed (Saviotti and Pyka, 2004).

New sectors and markets are going to open up, allowing for people to look for different employment opportunities because once the possibilities of increasing efficiency and lowering the cost are exhausted, enterpreuners are going to look for new opportunities of temporary market monopolies (Schumpeter, 1912). Considering labour and automation as two different ways of production, there is a possibility that labour could disappear being replaced by the automation (Aghion, 1998), but if we allow for diversity to enter the scene, variety will grow, allowing for new opportunities and ideas (Saviotti and Pyka, 2004). Since many of the technological developments are not yet fully realized, we are likely to see a further substantial increase in the gains from future productivity (Basu and Fernald, 2007). Anyhow, such increase in productivity is going to contribute to the new research and innovation processes which are necessary for further development of our economic system and the society.

The transition process is going to be slow and governments have to prepare for the forthcoming changes in order to be able to give a timely response to the awakening of new industries, sectors, and maybe a completely new environment. In the next chapters, we discuss what should be the primary direction of such interventions and the consequences of robotics and artificial intelligence on education and society as a whole.

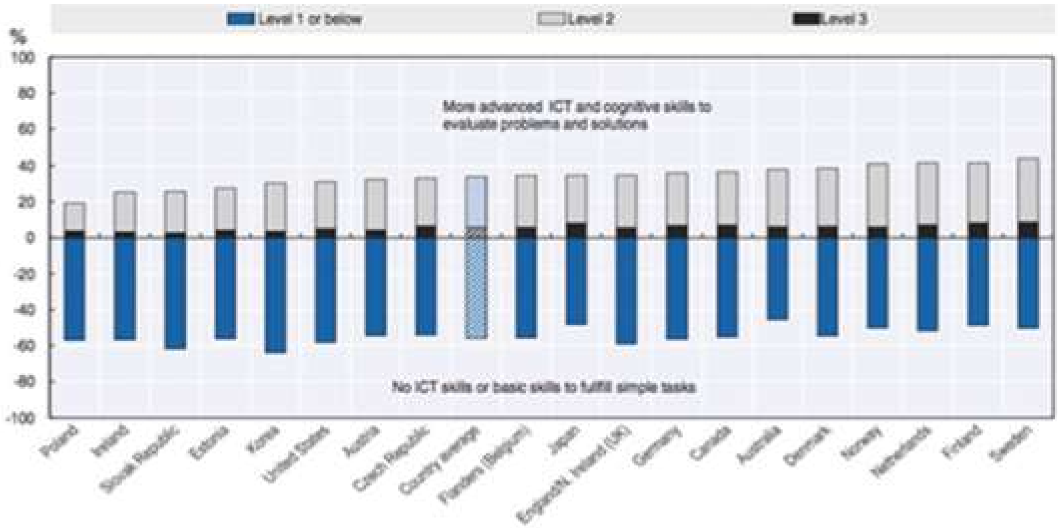
6. THE INFLUENCE OF TECHNOLOGY ON EDUCATION

The expression "race between machine and man" became a synonym after the introduction of robotics led to technological unemployment. As the introduction of robots is starting to influence many different areas, this race is narrowing down to a particular sectors. In the case of technology and education, Frey and Osborne (2015) observed that the race is on an unequal footing, since the former occurs rapidly and disruptively, while the latter very slowly. Such an inequality is mirrored down in the mismatch of the demand and supply of highly skilled employees, which has to be addressed by the governments and policy makers.

6.1. WHY SHOULD EDUCATION CHANGE?

For many years now, knowledge intensification and globalisation have been widely considered to be the most important challenges with which industrialised and industrialising economies are confronted (Pyka and Hanusch, 2006) and even till today, many countries are struggling to develop the necessary skills.

OECD data reveals that 7 to 27 percent of the adults in OECD countries still have no experience in using computers, or lack the most elementary skills. Only 6 percent of people have the "highest level" of ICT skills. In countries such as Austria, the U.S., Korea, Estonia, the Slovak Republic, Ireland, and Poland, the share is 5 percent and below (Figure 9).

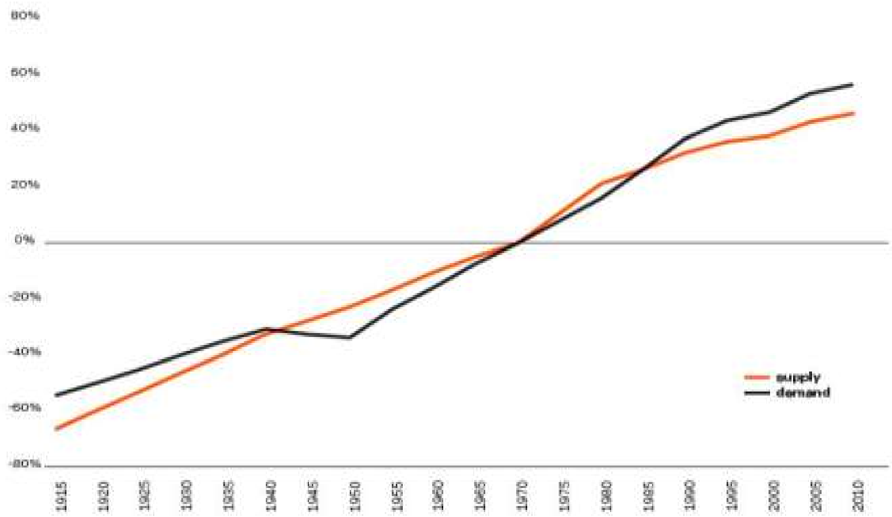


Source: OECD, 2014

Figure 9: Level of proficiency in problem solving

These results are quite discouraging because, as shown in Figure 10, the period from 1985 to 2010, which was characterised by a remarkable increase in the demand for college educated workers, saw the supply slightly decreasing, which reflects the inability of the education system to concordantly adapt to the necessities of the labour markets. In addition to the fast increase in the demand for upskilling with respect to its supply (Brynjolfsson and McAffee, 2012), the increase in supply coupled with higher pay, points unmistakably to an increase in the relative demand for skilled labour (Frey and Osborne, 2015). Such a shift could be explained through the private actors' competition struggle, where they keep reinventing the business in order to get the most from their technology. For this purpose, they require radically different and higher skill levels in the workforce. In particular, soft skills like leadership, team building, and creativity become increasingly important. These are the areas least likely to be automated and most in demand in a dynamic, entrepreneurial economy. Consequentially, college graduates who seek traditional types of job, where someone else tells them what to do each day, will find themselves increasingly in competition with machines, which excel at following detailed instructions (Brynjolfsson and McAffee, 2012). As discussed in the previous chapters, the technological trend is lowering the value of mechanical labour and thus the economic value of bodies is declining. As a result, the intrinsic capital value of human brains is increasing and we see the rise of a new inherent human capital –

personal



preference (Pratt, 2015). But the question here is, if the robots coupled with AI are increasing becoming humanoid, what our true capital is going to be?

Source: Goldin and Katz (2008)

Figure 10: Relative demand and supply of College educated workers

Doctors, lawyers, accountants, business consultants, scientists, architects, and other professionals regularly use specially designed information technologies to assist them in their professional endeavours, and some believe that with further technological improvements, it is about time when these machine assistants will be able to completely replace them (Riffkin, 1995). However, as discussed in Chapter 4, if we take a look at these occupations through the lens of a dynamic economic system, those replacements (if any) could go hand-in-hand with new job openings in different sectors and fields. For instance, information technology especially makes passive leisure more interesting and cheaper. Therefore, the demand for leisure offers is likely to increase. Companies like Netflix and Spotify have recognised this trend, and many others are following them (Frey and Osborne, 2015). Moreover, as the companies are becoming more socially responsible, the question of ethic and social acceptability has to be taken into account. Who would be responsible for medical failures or crashed buildings if the robots would be the one curing or building? All these interdependencies between the different aspects of innovation, in particular robotics and AI, create a complex picture that cannot be easily deciphered.

As previously argued, technological progress shifted the composition of employment and the demand for skills (Frey and Osborne, 2015). Robotics, computerised inventory control, and automatic transcription have been substituting routine tasks, while other technologies like data visualization, analytics, high-speed communications, and rapid prototyping have augmented the contributions of more abstract and data-driven reasoning, thus increasing the value of these jobs (Brynjolfsson and McAffee, 2012). It is evident that the increase in the demand for skills is closely correlated with advances in technology, particularly digital technologies (Autor, Katz and Krueger, 1998). However, in spite of the “invading machines” and the changes in skill requirements, governments are not promptly adapting the education to the current and future needs of the labour markets.

According to the European Commission, about 47 percent of European workers have insufficient digital skills, while 23 percent of them have none at all (European Commission, 2013). When it comes to the United States, the educational progress has stalled as well, which is highly reflected in the stagnating wages and fewer jobs. The United States used to lead the world in the education of its citizens, but the high costs and low performance of the American education system has lowered the productivity of this sector (Brynjolfsson and McAffee, 2012). Moreover, developing countries are worse off than commonly perceived, as proven from the common data on enrolments and school attendance (Hanushek and Wossmann, 2007). Thus, the problem in education is two-fold: Firstly, there are many developing countries where the school attendance is still low and secondly, the developed countries are not promptly adapting their education to the changing labour market, skills, and society in general. We are going to focus on this aspect, as the education system, currently in place, is not preparing humans for the world of intelligent machines, where machines could go to work instead of humans, work with us or increase our leisure time as well as our time for social relationships and personal preferences.

6.2. HOW SHOULD EDUCATION CHANGE?

For the past couple of decades, we have been getting used to live in a standardized world where education, among others, has not seen any major changes or disruptions. As pointed out by Brynjolfsson and McAffee (2012), "basic instructional methods, involving a teacher lecturing to rows of passive students, have changed little in centuries". In the near future, we hope to see such lecturing methods changing because the rapid technological alterations are challenging the adequacy of our skills and competences. With the remarkable improvements in robotics and frequent disruptive innovations, we have arrived at the point where education should be considered as a continuous work in progress. New production technologies raise the importance of interdisciplinary education and research, while the greater interaction between industry and education is becoming particularly important. Moreover, life-long learning and workplace training are also becoming essential, so that skill upgradation match the pace of technological change.

Digital skills and skills which complement machines are gaining a vital role. Moreover, the importance of strong generic skills - such as literacy, numeracy, and problem solving - as a basis for learning fast-changing specific skills should be taken into account when creating new educational frameworks (Brynjolfsson and McAffee, 2012). The road to improvement is going to involve major structural changes which will not follow from simple additions to resources (Hanushek and Wossmann, 2007). Such a structural change have to follow the technological advances and match the velocity of robotics and AI. Brynjolfsson and McAfee (2012) suggest the "race with machines" strategy, where people would not chase the machines but work together with them.

They recommend organizational innovations and co-inventing new organizational structures, processes, and business models that leverage the ever-advancing technological developments and human skills. For instance, Google, Facebook, and

Apple have created remarkable shareholder values by creating new product categories, ecosystems, and even industries. These new platforms leverage technology to create marketplaces that address the employment crisis by bringing together machines and human skills in new and unexpected ways (Brynjolfsson and McAfee, 2012). Such an approach to the education system would follow the dynamic aspect of evolutionary economics we previously discussed, as the economic development is about both efficiency and variety. Not only should the education system be able to catch up with the new emerging fields, but we should also instigate a systematic change in the entire educational framework and nature. For instance, today we observe the new phenomenon of freelancing, but does education really prepare us for it? As for now, education is not teaching us to follow our passion, but the orders. Therefore, we believe that the education system should be redressed so that it is able to prepare us to be the freelancer– capable, passionate, and self-determined individuals.

Moreover, digital technologies create enormous opportunities for individuals to use their unique and dispersed knowledge for the benefit of the whole economy. There are always new combinations to try and there are many examples pointing towards the benefits and advantages of the inclusion of robotics and artificial intelligence into the education system. So, not only should the system of education change, but also the way of teaching. For instance, robotics influences many educational aspects and has a great impact on students´ abilities and skills. A study by Khanlari (2013) shows that robotics is an effective tool for improving twenty-first century skills, including students´ creativity, collaboration and team-work, self-direction, communication skills, social and cross-cultural skills, and social responsibilities. Therefore, robotics can be used as an effective tool to prepare students but also offer a playful and tangible way, for children, to engage with concepts of technology during their foundational, early, childhood years.

A study conducted by Sullivan and Bers (2015) looked at children, from pre-kindergarten through second grade, who completed an 8-week robotics curriculum in their classrooms, using robotics construction kits specifically designed for young learners combined with a tangible programming language. Results showed that, beginning in pre-kindergarten, children were able to master basic robotics and programming skills, while the older children were able to master increasingly complex concepts using the same robotics kit within the same amount of time. This study provided preliminary evidence that technological tools can be useful and educational, even in early childhood classrooms (Sullivan and Bers, 2015). Coming to secondary education, Primary Sources: America´s Teachers on America´s Schools is a report consisting of several research phases, culminating in the largest-ever national survey of more than 40,000 public school classroom teachers.

Figure 11 shows that 57 percent of these teachers think that technology engages students in learning. Moreover, teachers overwhelmingly agreed that a high school diploma is not enough to prepare students for success in a changing world. They believed that unprecedented challenges must be faced by this generation, and they recognized the disconnect between the students´ current levels of achievement and the levels at which they must perform to achieve success in an increasingly competitive global economy (Mayer and Philips, 2010).

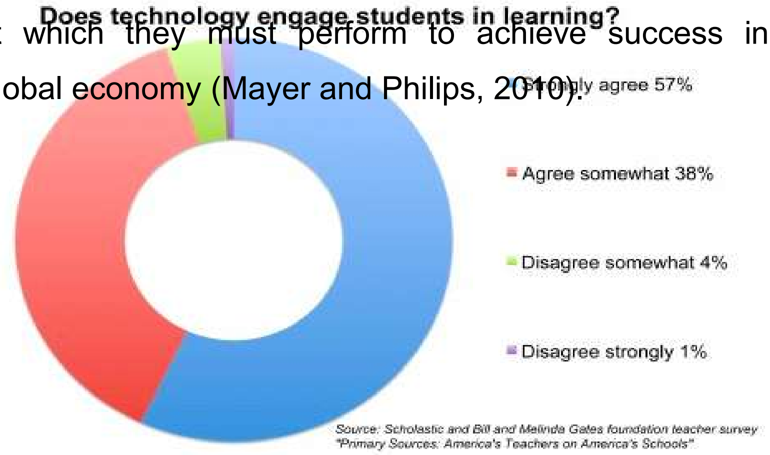


Figure 11: Technology engagement

Robotics and artificial intelligence could be considered as the tremendous upside potential for improvements in innovative teaching systems and education in general. As education becomes increasingly digitized, educators can probe, analyse, and track different approaches, measure and recognize what works, share the findings, and replicate the best approaches in other subjects. This would enable a faster pace of innovation, leading to further improvements in educational productivity (Brynjolfsson and McAffee, 2012). However, in order to enrich the social and the soft skills of students, some kind of a combination of in-class teachings and online networks should be implemented. Local human teachers, tutors, and peer tutoring can easily be incorporated into the system to provide some of the values that technology cannot teach well, such as emotional support and less-structured instructions or assessments.

As previously mentioned, the supply of skilled workers is correlated to the rate of skill-biased technological change. Therefore, there should be higher investment in education for skilled labour, since an increase in the stock of skilled workers spurs R&D activities, that result in new technologies which are complementary to skilled workers. Consequently, stimulating skill formation with educational subsidies will not only increase the relative supply of skilled workers, but also their relative demand (Jacobs, 2004). The transition process of the education system has to be systematically planned and adjusted to the most recent developments and innovations. Investments in knowledge, education and learning are the driving forces of economic success and if this does not happen, we may end up in a society where education will not be the driver of progress leading our societies into the trap of redundant labor and useless skills.

7. INFLUENCE OF ROBOTICS AND ARTIFICIAL INTELLIGENCE ON THE SOCIETY

Many years ago, Havelock Ellis (1922) argued that, “The greatest task before civilization at present is to make machines what they ought to be, the slaves, instead of the masters of men.”, and it is interesting to notice that, a couple of years ago, professor Stephen Hawking stated that “the development of full AI could spell the end of the human race” (Cellan-Jones, 2014). The increase of technological unemployment is a fact that, with incredible technological advances, could easily transform into the chronic unemployment which Don Peck (2010) described as “a pestilence that slowly eats away people, families, and, if it spreads widely enough, the fabric of society.” Are the machines going to swallow our society?

Expectedly, people are worried. For instance, less than 20 percent of American workers believe that the generation currently entering the workforce will have better lives than themselves (Frey and Osborne, 2015). AI technologies and robotics have the potential to transform society, but they also raise a range of ethical, regulatory, and social issues. As previously argued, AI can stimulate innovation and boost economic productivity, yet it is a knife with two blades. On the one side there are the capitalists, futurists, and political leaders who perceive the Industry 4.0 as the golden era of unlimited production and rising consumption. The other side is reserved for the people who are becoming redundant due to automation and new technologies. For them, the future is filled with despair and growing anxiety.

Concerns about the risks, benefits, and ethical issues associated with these technologies appear to be growing. In Europe, fear over rising unemployment is leading to wide-spread social unrest and emergence of neo-fascist political movements. What is going to happen to our society and what are the possible outcomes? Campa (2014) provided speculative predictions about four possible outcomes. Firstly, he described the *unplanned end of work* scenario which could be generated as an outcome of technological growth or in the case where political and economic systems do not change. The *planned end of robots* scenario could be generated as outcomes of technological de-growth or a radical change in the political and economic system. The *unplanned end of robots* scenario could be generated by the Keynesian approach per se. If the robotic industry is heavily taxed, the whole population would remain without an income, which would lead to de-industrialization.
Finally, the *planned end of work* scenario could be generated as an outcome of technological growth or a radical change in the political and economic system. Programmed growth or the social redistribution of wealth could also lead to the increase of human leisure time. Anyhow, the four demonstrated scenarios do not take into account the dynamics of economy and the intrinsically uncertain nature of innovation. Even in the case where technological growth continues to rise, there is the possibility of variety increase.
Variety increase goes hand-in-hand with increase in efficiency (Saviotti and Pyka, 2004) and, as demonstrated through the idea of creative economy, once the saturation of demand is achieved, the industry cycle is going to lead entrepreneurs to open up new markets and eventually initiate different industries and sectors that will lead to new labour markets.

7.1. ROBOTICS AND AI– A THREAT OR HOPE?

Robotics and artificial intelligence are technologies in symbiotic relationship reflecting a complex sector of innovation that, as presented in this paper, could be perceived through two different standpoints. On the positive side, these technologies are going to open up new markets, initiate new industries, and radically change our environment. On the other hand, static analysis of current employment rates and automation levels threaten us with a negative picture of labour markets and lost societies.

We strongly believe that robotics and artificial intelligence will eventually find its way to enrich our economic system, but what are the actual threats of technological unemployment? Conforming to Riffkin (1995), rising unemployment and loss of hope for a better future are among the core reasons for increasing violence and theft. In the United States, a one percent rise in unemployment results in a 6.7 percent increase in homicides, a 3.4 percent increase in violent crimes, and a 2.4 percent increase in property crimes (Fowles and Merva, 1996). And, if we take a look from the sociological perspective, these homicides and the related crimes and thefts are not merely a result of individual intentions, but of the social environment of the individuals (Durkheim, 1897). The increasing violence is evident all over the world. French sociologist Loic Wacquant (2009) proves that communities that riot share a common sociological profile, where most of the people are former workers that have been left behind by the transition from a manufacturing to an information-based society.

Taking a positive stand, the society with less work or without any work at all is likely to lead to a shortening of the workweek and therefore, providing more time for leisure. Already, in 1930, John Maynard Keynes predicted that our society could end up facing this dilemma on how to use our freedom from economic cares and occupy our leisure. Riffkin (1995) claimed that this may lead to the increase in prostitution and violence, but the truth is that many may turn to the informal economy, using their talents and energy coupled with leisure hours and idle time to rebuild local communities and create a third flourishing force, independent of the marketplace and the public sector.

7.2. PUBLIC ACCEPTANCE

Previously discussed hope and threat aspects of robotics and AI depend largely on the public acceptance of technology as a part of their daily life and environment. Rising unemployment and social issues could strongly affect the use and adoption of technology itself, because it depends on the social and political contexts into which it is placed (Gupta, Fischer and Frewer, 2012). In Europe, for instance, the negative public sentiment on Genetically Modified Organisms (GMOs) has resulted in lower funding levels, high regulatory rejection rates, and lower levels of innovation than in other jurisdictions (Currall, 2006). Depending on the nature of innovation, such negative sentiments could influence our economy in a two-fold way: (i) in the case that it is present worldwide, a stagnation in innovation will lead to a decrease in variety and eventually to a decrease in economic development, and (ii) other markets, which enjoy present public acceptance will take a lead market position and gain competitive advantage. Therefore, in both cases, the results are obviously harmful, for the market in the short-term and an entire country and the world in the long-term.

Development and adoption of production technologies affect labour markets in significant ways, which is raising serious questions about the public attitudes and acceptance of these new technologies. Historically, public opposition was present in a number of fields of emerging technology such as nuclear power, genetically modified organisms, and many others. Therefore, future progress and wide adoption of robotics and AI depends strongly on public acceptance, because public concerns can shape the direction, pace, diffusion of innovation, and even block its progress (Gupta, Fischer and Frewer, 2012). For instance, emerging technologies have sometimes been blocked because of social and ethical concerns. The very concept of intelligence, human and artificial, is subject to different interpretations in different cultures (Veruggio, Operto and Bekey, 2016). Anyhow, public resistance is a delicate aspect that has to be treated with scrutinity to the concerns and issues which drive such oppositions. Following this reasoning, path of responsible innovation should give rise to regulations that promote trust and confidence, and steer innovation along acceptable pathways (see for example Koops, 2015; Jacob et al., 2013; Von Schombeg, 2013). Responsible innovation is a prominent aspect nowadays, where it is argued that the process of research and innovation should be aligned to the values, needs, and expectations of the society, requiring all the stakeholders to be responsive to each other and take responsibility for the processes and its outcomes (Jacob et al., 2013). There are a couple of issues which arise in understanding and applying this concept, but we shall find out a scope to discuss them. To sum up, public acceptance is one of the most important drivers for the complete application of robots and AI in different spheres of our lives, but it is also an important tool that has to be carefully dealt with as, in many cases, it is rooted in the real problems and issues that the society is burdened with.

8. FUTURE POLICY

Robust mechanisms for addressing the risks, benefits, and ethical issues arising from robotics and AI are not yet institutionalised (Calo, 2014), and in order to avoid a further increase in violations, protests, crimes, and social unrests, governments have to start implementing policies which will be able to cope with technological unemployment and the introduction of robots and AI in general. This is an extremely difficult task, especially nowadays when the disappearing role of human labour is coupled with the diminutive role of the government as well. Global companies are, to a great extent, subsuming the power of nations and transnational enterprises have increasingly usurped the traditional role of the state (Riffkin, 1995).

However, not everyone agrees that there should be policy implementation. AI is still in the process of being developed, and some view policy interventions around AI with scepticism, arguing that it is too early for such actions (Brynjolfsson and McAfee, 2015). However, others disagree (Brundage and Bryson, 2016), holding that “AI is already sufficiently mature technologically to impact billions of lives trillions of times a day” and science and technology regulations could also be pro-innovation and not explicitly restrictive in nature. Some scholars have already provided possible solutions. Riffkin (1995) argues that the productivity gains, resulting from the introduction of new labour-saving and time-saving technologies, should be shared with millions of working people. He also claims that the shrinking of mass employment in the formal market economy will require greater attention on the non-market economy, where people would look to help address their personal and societal needs that can no longer be dealt with by the marketplace or legislative decrees. This is the arena where humans could explore new roles and responsibilities. Frey and Osborne (2015) offered a slightly different solution, proposing public job guarantees. They claim that public job guarantees for those displaced could boost the effective demand; and “in the event that supply continues to outpace demand due to technological change, policymakers may take deliberate steps to reduce supply by implementing more work-sharing policies to spread job tasks across a broader pool of available workers.”These solutions seem sound and promising only in the scenario of the emergence of a “non-working society”. Nevertheless, such a scenario seems more like a dark prediction, when seen through the lens of a classical economy. What happens if new sectors emerge or radical innovations enter the scene?

We believe that simple predictions or solutions do not exist, as the nature of these technologies and their application as well as the societal response towards them, are all multifaceted. The complex nature of these technologies and wicked aspect of the problems that might occur, do not allow us to propose any unique solution or a simple answer. Anyhow, governments should take into account all the above-mentioned aspects, namely, technology, education, and public acceptance (society).

When it comes to automation, we use the framework introduced by Stilgoe et al. (2013) where they take into account four possible dimensions of responsible innovation. The introduction of robotics and AI is still a new phenomenon, whose application and final effect is not easily predictable. The framework is generalized and could be applied to any technological field, so we modified and adapted it to suit the field of robotics and artificial intelligence, in order to assess the responsibility aspect of these technologies. Therefore, Table 2 describes the possible factors that could influence future policy creation, which are in line with four dimensions, namely, anticipation, reflexivity, inclusion, and responsiveness. We suggest that governments, when framing the regularities and prospective policies, consult the framework and take into account all possible dimensions important for the development and regulation of these technologies.

Dimension	Factors for policy creation
Anticipation	Foresight of the effects of automation on the industry, financial sector, and society. Assessment of robotics and artificial intelligence. Scenario analysis of non-working societies or low working hours. Envisioning the world where robots and AI would dominate the market.
Reflexivity	Multidisciplinary collaboration between the different stakeholders involved. Inclusion of social scientists and ethicists in AI and robotics development. Ethical assessment of robotics and artificial intelligence. Provision of codes of conduct for development, marketing, sales, and inclusion of AI and robotics in production and services.
Inclusion	Organization of panels for citizens in order to enhance public acceptance and analyse resistance and opposition drivers. Foster up consensus conferences on robots and AI application and usage. Organization of focus groups and science shops to discuss future policies for robotics and AI diffusion.
Responsiveness	Provision of regulations and standards for AI and robotics application. Open access and other mechanisms of transparency to foster further innovation and growth in variety (emergence of new sectors). Strategic policies and roadmaps for further development.

	Change in the institutional structure and culture.

Source: Stilgoe et al. (2013); authors adaptation

Table 2: Application of responsible framework to robotics and AI

Education is an aspect we previously discussed and we find important to stress the fact that many policy-makers are concerned by the consequences of unpreparedness in a context of rapid but hard-to-foresee technological change. This is reflected by the German Chancellor Angela Merkel who asserted at Davos, in 2015, “I want our strong German economy to be able to cope with the merger of the real economy and the digital economy, otherwise we will lose out to the competition.” (Merkel, 2015). The OECD (2016) report shows that unpreparedness might take various forms – from skills and infrastructure deficits to regulatory shortcomings – and have numerous consequences. Corollary to the risk of machine-driven labour displacement, automation might also undermine labour-cost advantages, on which many emerging economies rely. Therefore, it is urgent for goverments to react with structural changes in education framework adapted to emerging industries, digitalization and new environment.

Related to the societal aspect, a large number of human beings could be liberated from long hours of labour, but the same technological forces could easily lead to growing unemployment and therefore, global depression (Riffkin, 1995). The national context and government policies affecting technological diffusion shape the environment in which organizations adopt robots and thus it impinges indirectly on robot diffusion (Fleck and White, 1987). Resilience and prosperity will be more likely in countries with modern development policies, better functioning institutions, better educated and informed citizens, and critical technological capabilities in a number of sectors (OECD, 2016). Thus, in order to stay competitive in a global arena and ensure the prosperity of its citizens, countries should start to invest heavily in education and technology simultaneously, which will positively influence the society and the public.

According to Marcus (1979), automation threatens the rendering of a possible reversal of the relation between free time and working time: the possibility of working time becoming marginal and free time becoming full time. Such a reallocation of time would result in a radical transvaluation of values, incompatible with traditional culture. Moreover, technological utopians argue that properly harnessed science and technology will eventually free human beings from formal work, in all respects. The famous architect of Japan´s computer revolution, Masuda, agreed with Marcuse that the computer revolution opens the door to a radical reorientation of society, away from regimented work and toward personal freedom for the first time in history (Riffkin, 1995). However, most of the structural reforms are long-term initiatives that will take time and effort. In the short-run, there is the possibility of shortening the workweek and increasing leisure for everyone. Leontief (1983) admitted that the emerging knowledge sector will not be able to create enough new jobs to absorb the displaced workers. He favoured a shortening of the workweek as a means of sharing the available work. The shortening of working time is not a new phenomenon. We learned, from the first stage of the Industrial Revolution in the nineteenth century, that great productivity gains should be followed by a reduction of work hours.

Similarly, in the twentieth century, industrial economies made the transition from steam technologies to oil and electric ones, where the increases in productivity led to a further shortening of the workweek from sixty hours to forty. Nowadays, a growing number of observers are suggesting that the productivity gains from computers, robotics, and AI, should inevitability lead to a further reduction of work hours, to thirty and even twenty hours per week, to bring labour requirements in line with the new productive capacity of the capital (Feris, 2011; Hill, 2001; Härmä, 2006). The demand for a shorter workweek is being actively promoted. Since governments are not being able to intervene with their tax and public projects, many see the shorter workweek as the only viable solution to technological displacement. For instance, in the United States, interest in the shorter workweek has spread from labour leaders and policy analysts to the public at large. A large number of Americans say they would trade a part of their income gains for increased leisure, in order to attend to family responsibilities and personal needs (Riffkin, 1995).

To sum up, public understanding and acceptance of new production technologies matter, and there is a close connection between public resistance to new technologies and the disruption of trust in scientific and regulatory authorities (OECD, 2016). Moreover, governments must take the necessary steps to foster the application of robotics and AI into the direction of responsible actions that take into account people, profit, and the planet (Blok and Lemmens, 2015). Finally, education is an important knowledge generation tool that has to undergo a transformation, in order to adapt to the forthcoming shift in skills and capability requirements. Therefore, policy makers and institutions should voice realistic expectations about technologies while duly acknowledging its uncertainties and prepare the society for the new era of Industry 4.0.

9. CONCLUSIONS AND OUTLOOK

What will be the final effect of robotization and application of AI? The most remarkable positive as well as negative consequences are likely to be expected in labour markets.

On one hand, most recent technological developments seem to spare neither high-skilled nor low-skilled workers. For instance, at Northeastern University, there is a research group working on robots in creating motions – combinations of arm, wrist, finger, and thumb movements – that could collectively accomplish a task, like moving a wrench in a circle to tighten a bolt, or pulling a cart from one place to another (Padir, 2017). These robots are promising new versions of humanoids that are able to perform even the most complicated tasks. Thus, many service activities and low-skilled production processes are likely to be overtaken by robots which are able to perform fine motions and movements. Moreover, with the so-called deep learning methods, robots are likely to replace even the most demanding intellectual human occupations in the not-too-distant future.

McAffee and Brynjolfsson (2012) depict this fast changing environment saying that the “computers (and other technologies) improve so quickly that their capabilities pass from the realm of science fiction into the everyday world”.

On the other hand, it depends on us regarding how we use these robots and AI. As previously discussed, robots may also be used to assist employees, such as in healthcare, nurses may be relieved of hard-work with robots helping patients and elderly persons (Frey and Osborne, 2015), which would allow nurses to spend more social time with patients. Moreover, with emerging industries and new sectors, new job titles are growing (Lin, 2011), and increasing use of advanced ICTs, such as data analytics, has raised the demand for new types of skills. Moreover, digital revolution requires less capital investment, allowing innovators and entrepreneurs, who could also be private individuals or consumers, to innovate further, leading to higher economic growth and development.

Remarkable productivity growth brought with robotization and AI is necessary condition for further development, because the financial resources created this way can be used for novel developments and investments (Kuznets, 1965). Therefore, economic development is a process that goes hand in hand with efficiency and growth variety (Saviotti and Pyka, 2004), But, by definition, we are not capable of foreseeing the final impact of these technologies. They might replace us, help us, or create new jobs and a different environment for us.

However, we have to keep track of these changes and provide sound regulations for the new technologies and automation as well as enable transparency in and policies for our society and education system, that are going to be able to prepare us for a future that might look quite different in a decade or two. In particular, highly specific skills such as proficiency in high-tech applications and coding are becoming essential, and it would be a good sign to include these kinds of subjects in primary and secondary schools. Policy makers have to start developing the framework to regulate issues like technological unemployment, skill scarcity, and responsible innovation as well as foster public acceptance with transparency and inclusion. We have proposed the framework for responsible technology assessment, which could be a good starting point that can further include already described policies such as shortening of the workweek, ethical and social regulations of robotics and AI. Moreover, the policies for further technological developments, which together should contribute to building trust, in order to encourage the public acceptance of innovations, should be included as well.

The pool of experts forecasting technological developments are largely consistent in their predictions for the evolution of technology itself. The vast majority of

respondents to the 2014 Future of the Internet canvassing anticipate that robotics and artificial intelligence will permeate wide segments of our daily life by 2025, with huge implications for a range of industries.
However, they are deeply divided on how advances in AI and robotics will influence the economic and employment picture over the next decade. Namely, 48 percent of them visualize a future where robots have displaced significant numbers of both blue-collar and white-collar workers. They predict an increase in the demand for highly skilled workers. But far more people will be displaced and pushed into lower paid service jobs or even permanent unemployment (Smith and Anderson, 2014). However, 52 percent are optimistic and expect that technology will not displace more jobs than it creates by 2025. They expressed faith in human ingenuity in creating new jobs and industries (Smith and Anderson, 2014).

The two divided pools of opinion manifestly describe the Janus-faced character of robotics and artificial intelligence. The actual development will strongly depend on many different conditions and this poses several important questions: How can we design a beneficial education system adapted to the new environment of human-robot relationships and be able to provide the skills for the remaining and novel occupations in the future? How can we organize a fair income distribution that guarantees social stability in the long-term? Finally, how can we foster responsible innovations and include ethical and social aspects into robotics and artificial intelligence?

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ANNEX

Declaration*

I,

Surname, First name OMEROVIC MIRHETA

Matriculation number 675040

declare that I have followed the Principles of Good Scientific Practice while writing the present

- [ ] Bachelor's thesis.
- [x] Master's thesis,
- [ ] seminar paper.
- [ ] Diploma's thesis.

I have written the paper/thesis independently and have used no other sources or aids than those given and have marked the passages taken from other works word-for-word or paraphrased.

Supervisor

PROF. DR. ANDREAS PYKA

Topic of the paper/thesis

THE JANUS-FACED CHARACTER OF ROBOTICS AND ARTIFICIAL INTELLIGENCE