

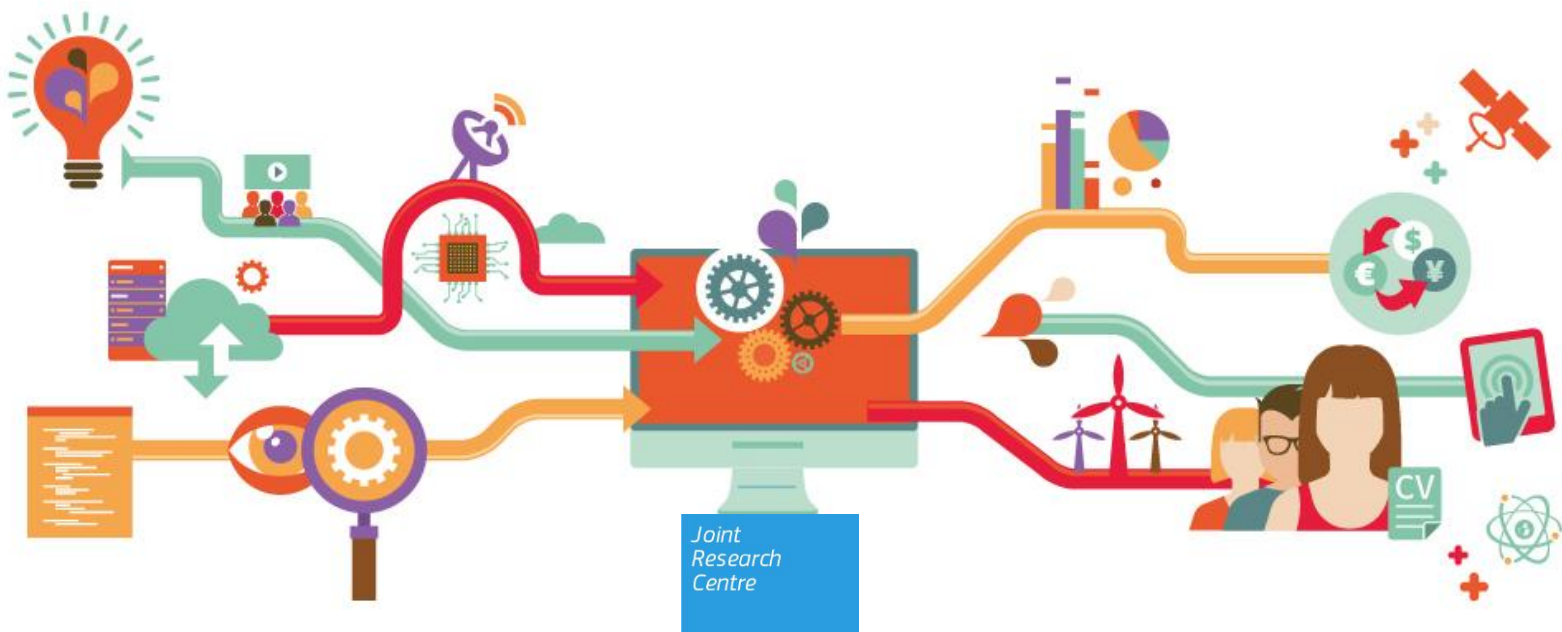
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What are the policy options? A systematic review of policy responses to the impacts of robotisation and automation on the labour market

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What are the policy options?

A systematic review of policy responses to the impacts of robotisation and automation on the labour market¹

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Abstract

Three main policy responses to the labour market challenges posed by robotisation and automation have emerged in the research literature. The first is ‘taxing robots’ and using this revenue to introduce a basic income that could offset the negative impacts of replacing humans by robots. The second option highlights the ownership of robots so that taking part in the new source of wealth is possible. The third focuses on strengthening the comparative advantages, the creativity, and the social intelligence of humans that robots will never be able to match. All of these policy responses are supported by economic rationales and research findings but a systematic review shows that all of them raise further questions and challenges that should be carefully investigated in order to choose the right path. This paper offers a comprehensive overview of these questions. Furthermore, in a broader sense these policy options—redistributing the benefits of technological changes, increasing accesses to the benefits and utilisation of changes, and supporting the individual and institutional adjustment to changes—are relevant to every technological transformation. Hence, the lessons that are drawn from the current discussion of policy options driven by specific technologies, robotization, and automation might serve as a precursor to potential policy responses triggered by other technologies.

Keywords: robotisation, automation, policies, industrial transformation, labour market, innovation, territorial development

JEL Classification: J08; O30; L51

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1. Introduction

In this subject, three main policy solutions for the labour market challenges posed by robotisation and automation emerge from looking at the ever-growing research literature. All of them are mostly at an experimental stage, and have a more redistributive and more free-market variety (see *Figure 1*). All of them are based on particular assumptions, theoretical backgrounds, and research evidence and estimates (Chapter 2). And all of them raise further questions and challenges that should be carefully investigated in order to choose the right path (Chapters 3 and 4). These policy options are:

- *‘taxing robots’* or, more precisely, their owners, which could be used to finance the basic income that might be universal or subject to conditions;
- increasingly *becoming the owners of robots*, which may take the form of collective ownership (ownership by the state, a cooperative society, or a small community), or as part of an individual’s accumulated assets;
- *trusting the comparative advantages of humans*, i.e. humans developing their skills and competencies—creative and social intelligence—which robots will never be able to match. This can also manifest itself in state-sponsored training programmes and education reforms or the independent and lifelong learning of individuals.

Figure 1: Policy options for the labour market impact of robotisation and automation (modified, Cséfalvay, 2017, 118)

policy options	policy ranges	
	redistributive	free-market
‘taxing robots’	universal basic income	basic income with incentives
ownership of robots	collective (state, cooperative society, small community)	individual
strengthening the comparative advantages of humans	state training programmes, education reforms	individual training and improvement of skills

2. Initial assumptions, theoretical background, and research findings

2.1 ‘Taxing robots’

2.1.1 Initial assumptions

The incontrovertible conventional wisdom during the last decade has been that robotisation and automation will mainly affect simple, routine physical and intellectual occupations and tasks (Autor at al., 2003; Levy and Murnane, 2004; Acemoglu and Autor, 2010). However, due to the latest technologies such as Artificial Intelligence, Big Data analysis, and the Internet of Things, it has become clear that robots are already capable of taking over *non-routine* physical and *complex cognitive tasks* from people too, and they will be even more capable of doing so in the future (Brynjolfsson and McAfee, 2011; 2014). The unwritten rule in the age of robots seems to be very simple: what can be automated, will sooner or later be automated, making human work redundant.

2.1.2 Theoretical background

The anticipated *technological unemployment* is not a new concept since it can be traced back to *Keynes* in the early 1930s, and similarly, the idea of a uniform income to offset the negative employment impacts of the rapid technological change partly goes back to *Einstein* at the same time ([Keynes, 1930/1963](#); [Einstein, 1933/2014](#)). What is *new* is the expected scale and scope of the transformation, and the assumption that today's technological change is fundamentally different from earlier industrial revolutions when a new industry or another economic sector absorbed the labour that became available due to the use of the new technology.

2.1.3 Research findings and estimates

The initial estimates show alarming numbers that have garnered considerable attention. According to the best-known study, which was conducted by [Frey and Osborne \(2013\)](#), almost *every second* job in the US may disappear due to robotisation and automation in two decades at most. Using their methodology, studies in Europe also indicate shocking figures in the same time horizon indicating that this transformation is a threat because it diminishes all jobs in Finland by 36%, 42% in France, and 59% in Germany ([Pajarinen and Rouvinen, 2014](#); [Roland Berger Strategy Consultants, 2014](#); [Brzeski and Burk, 2015](#)). Based on different methodology of routine task intensity ([Autor and Dorn, 2013](#)), [Lordan \(2018\)](#) also estimates that the jobs which could be automated in the European Union using today's frontier technology range from 38% of current employment in Ireland to 69% in the Czech Republic. In contrast and drawing a clear distinction between the jobs and the tasks that are done by the practicing of an occupation, the OECD calculates that *only 14% of jobs* on average in developed countries are highly automatable and expected to disappear (though this is, in summary, equivalent to 66 million workers in the 32 OECD countries analysed by the study) and an additional one-third of jobs will be substantially transformed ([Nedelkoska and Quintini, 2018](#)).

However, the public perception of future job losses indicates much higher figures, and the latest [Pew Research Center \(2018\)](#) survey shows between 65% (in US and Hungary) and 90% of the respondents (in Japan and Greece) think that in the coming fifty years robots will probably or definitely overtake the majority of jobs currently performed by humans. On average more than two-thirds of the respondents also believe that this process could further widen the *inequality between the rich and the poor*. Similarly, the latest special Eurobarometer Report highlights that while over six in ten European respondents (61%) have a positive attitude to robots and artificial intelligence, an even higher proportion, that is, almost three quarter of the respondents (72%) also agree with the statement that robots and artificial intelligence "*steal people's jobs*" and due to use of these technologies more jobs may disappear than new ones created ([European Commission, 2017, 59, 74](#)). Furthermore, these are the points where basic income could come into play ([Mason, 2015](#); [Standing, 2017](#)).

2.1.4 Suggested policies

In general, there are three arguments for the basic income. The first is the *simplification of the social security system* as this has become extremely wide-ranging, fragmented, and complex in almost all developed countries. The system's reform should therefore include simplification and perhaps even the introduction of unconditional basic income that would replace the current benefits. So this may be a budget-neutral solution, and the system could cut out red tape. However, according to estimates, the transition into a basic income would also be coupled with winners and losers (OECD, 2017; Browne and Immervoll, 2017).

The second argument is based on current labour market changes, specifically the spread of *self-employment* and the emergence of *digital labour platforms* (Pesole et al., 2018) connected to catchy names such as the gig economy or on-demand economy, and to new generations such as Millennials and Generation Z. More than this, according to an EU survey, the self-employed are at great risk of falling through the gaps in the social security safety net (Matsaganis et al., 2016) so the expansion of the social security safety net by adding basic income to it may close these gaps.

Finally, the third arguments is purely technological and a basic income for those who are left without a job due to robotisation and automation could offer a solution and help prevent society being torn apart by increasing inequality. The draft report of the European Parliament, which was rejected at the final voting, straightforwardly formulates the following: "in the light of the possible effects on the labour market of robotics and AI a general basic income should be seriously considered, and invites all Member States to do so" (European Parliament, Committee on Legal Affairs, 2016, 11). In contrast and to avoid idle rent-seeking, others would like to couple it with specific conditions by setting incentives, for instance, by providing a basic income that is conditional on educational efforts or voluntary community works (Ford, 2016).

Indeed, there are many ways in which revenues from taxing capital, in this case from 'taxing robots', could be used to compensate those who are negatively affected by technological transformation. Although this specific form of redistributive measure coupled to the idea of basic income in current debates has been gaining increasing attention despite the problems with its economic and financial feasibility and practical implementations in both the developing world (World Bank, 2019) and developed countries such as Finland (Pareliussen et al., 2018).

2.2 Ownership of robots

2.2.1 Initial assumptions

The second policy response relies on the hypothesis that competition between humans and robots will not be centred on jobs but much more around the *income* that can be earned in the workplace. As Freeman writes, "there is also nothing in economics that guarantees that the humans displaced from jobs by robots will end up with new jobs that pay as much as their former jobs or pay enough to attain a middle-class lifestyle" (Freeman, 2016, 38).

2.2.2 Theoretical background

The theoretical foundation of this policy option also goes back to the classics, in particular to *Ricardo's theory about the role of comparative advantages* in international trade and applies it in the context of price of industrial robots versus cost of human work. It is easy to concede that we can keep the jobs where we have a greater advantage in efficiency over robots, and companies will employ robots in activities where their efficiency is greater compared to humans. In addition, if robots were better and more efficient than humans in all fields, humans would still have jobs since robots are recruited in large numbers in fields where they have the greatest advantage in efficiency compared to humans and humans' other activities. Consequently, the real problem is not whether humans will have jobs in the age of robots but what type of jobs humans will have and, what is perhaps even more important, what wages will humans be able to earn in the jobs that humans are left with.

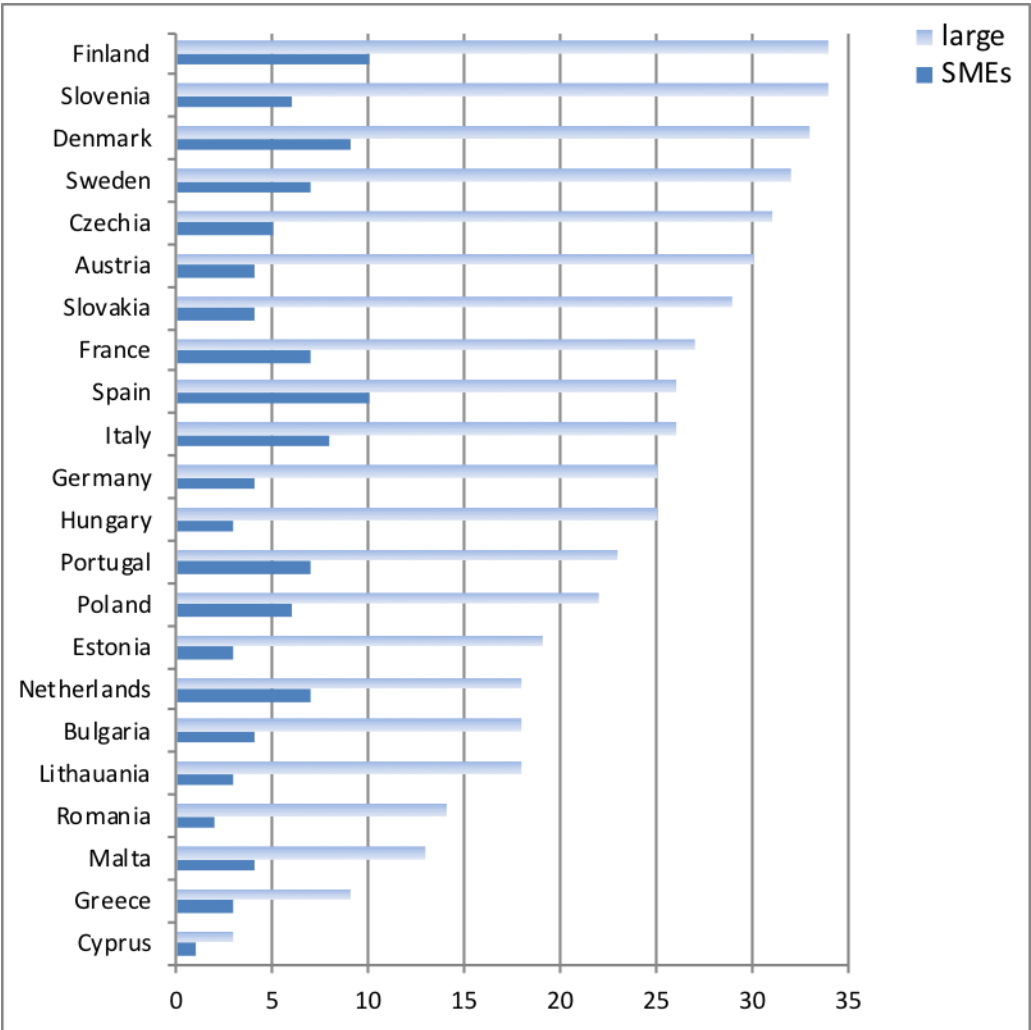
However, the handicap is that in the price/wage competition between robots and humans, it is the digital technology that dictates the pace of progress. Indeed, the performance of microprocessors at the heart of all IT devices has increased dramatically through the past five decades (Byrne, 2013; Pillai, 2012). On the other hand, and this is perhaps more important from an economic aspect, the price of the microprocessors offering the same performance has been decreasing at the same pace (Moore, 1975; Aizcorbe et al., 2008). In addition to the falling price of data management and processing, it is equally as significant that the price and unit cost of data storage has plunged just as dramatically while the speed and capacity of data transmission has also stunningly increased (Staune, 2015). If these trends—*diminishing costs of data processing, storage, and transmission*—holds true for the coming decades (and Cette (2015) formulates some concerns here) then the time might soon come in when purchase and operating costs of robots could be significantly lower than the costs of human work and this may put enormous downward pressure on wages

2.2.3 Research findings and estimates

Studies have already shown that the prices of industrial robots are constantly decreasing (Chiacchio et al., 2018) and the so-called *robots' payback period*, the period during which the price of a robot reaches the "price", i.e. the wages of the workers working two shifts who are replaced by robots, is similarly dramatically diminishing even in low-wage countries (Citigroup and Oxford Martin School, 2016).

At the time of writing industrial robots were mainly employed by global corporations and highly concentrated in a few regions and sectors (e.g. the automotive industry). Although in the context of the further drop in prices expected, there will be a turning point when industrial robots appear in large numbers in small and medium-sized enterprises that traditionally employ the majority of workers. The new industrial policy in the European Union, termed *Industry 4.0*, is partly aimed at fostering robotisation and automation in the SME sector. However, the latest EUROSTAT figures are showing that the current take-up rates for these technologies are still far from reaching that turning point (see *Figure 2*).

Figure 2: The use of industrial or service robots by enterprises in selected EU member states, 2018 (% of enterprises, SMEs with 10-249 employees, large enterprises with 250 or more employees)



Source: EUROSTAT (2018). 3D printing and robotics, [isoc_eb_p3d], last update 11.12.2018.

2.2.4 Suggested policies

In short, on the basis of the initial assumption, the lion’s share of income, new value, and profits in the recent technological transformation is not derived from labour but from capital, in particular, the capital invested in robots and the use of robots, and because the cost of robots is expected to fall, humans can only compete against robots for lower and lower wages in the long run. The only escape for humans is to increasingly *become robot owners* as that way many humans will directly benefit from the greater efficiency of robots’ work and the larger profits coupled with that. Therefore, Freeman argues for ownership rather than income redistribution, and for finding solutions that can make masses of people robot owners.

2.3 Strengthening the comparative advantages of humans

2.3.1 Initial assumptions

The third policy option agrees with the basic hypothesis of the first one, that is, what can be automated, will sooner or later be automated. However, it claims that there are two groups of tasks where robots cannot compete with humans, not even in the long term: activities that require *creative intelligence* (e.g. critical thinking, problem-solving, innovative reflection, creativity, intuition, and innovation) and activities that require *social intelligence* (e.g. cooperative skills, communication, human relationships, persuasion, agreement, assistance, and emotional support). Consequently, this policy response places more emphasis on the creation of *new jobs* than on the replacement of old jobs by robots.

2.3.2 Theoretical background

The idea that technological transformation is coupled with profound change in the employment structure is not a new one and goes back to *Schumpeter* in the 1940's. His concept of *creative destruction* highlights new technologies create new assets, new markets, new production methods, new industries, new companies and, perhaps most importantly, new jobs. In parallel with this or sometimes even earlier, the old assets, old markets, old production methods, old industries, old companies, and the corresponding old jobs in the fields of the old technologies rendered obsolete by the new ones disappear ([Schumpeter, 1942/2003](#)).

What is *new* is the nexus between Schumpeter's concept and the idea that the race between technology and jobs is to some extent a race between technology and education (let us now disregard the role of economic policy and demographics, among others). As [Goldin and Katz \(2008\)](#) argue in analysing the past one hundred years of the USA from this perspective, in the first half of the century, education raced ahead of technology, but later in the century, technology raced ahead of educational gains. Similarly, surveys in the European Union indicate that while in some job categories more than 90% of jobs require a specific type of digital skill, one in seven workplaces (15%) report the existence of a *digital skill gaps* in their workforce ([Curtarelli et al., 2016](#)), and on average more than 40% of the Europeans (16-74 year-olds) do not have basic digital skills ([Foley et al., 2018](#)). Put another way, *it is not technology that is way ahead, however rapid the current change feels, it is education that is falling behind.*

2.3.3 Research findings and estimates

Every study dealing with the future of work faces the fundamental challenge of how to *differentiate the non-routine physical and cognitive tasks* where machines can replace humans due to digitisation and automation from those where they cannot. The reason why various studies assess the impact on the labour market differently by orders of magnitude lies in where exactly they draw the border line between these tasks. For instance, [Arntz et al. \(2016\)](#) analysed the PIAAC survey by the OECD in which the adult respondents (16-65-year-olds) report how they use their skills and competences in their work, what exactly they

do, and what tasks they perform in their occupation, and came to the conclusion that Frey and Osborne and their followers significantly overestimated the effects of automation and digitisation.

Furthermore, a clear distinction should be drawn between tasks and work processes on the one hand, and occupations and jobs on the other. Autor's (2015) study shows that robots, of course, can substitute tasks and work processes and take away a portion or even the majority of it, but they rarely replace *entire occupations*. Robotisation does not necessarily mean that the occupations affected will also disappear, yet they may be *substantially transformed*. Studies assess that in developed countries around 25 to 60% of workers should expect that their occupation could be dramatically transformed in the future (Chui et al., 2015; OECD, 2016).

Finally, while by increasing capital intensity, robotisation and automation strengthen the job replacement process is a clear the trend, studies analysing the *current* employment effects at firm-level argue that these technologies may also be creating new jobs. Hence, the replacement of humans by robots might be only the first and initial effect on the labour market. According to Dauth et al. (2017), while each robot installed in Germany in the last two decades has destroyed on average two manufacturing jobs, this loss in the employment was entirely offset by spill-over effects and additional jobs in the service sector. Similarly, as a European Commission survey (2016a) calculates, the direct employment impacts of robotisation at *firm-level* in the manufacturing sector are at least neutral, or on the contrary, its positive effects on productivity and sales even stimulate employment growth.

2.3.4 Suggested policies

Since Schumpeter's idea of creative destruction is still relevant in the age of robots and the *expected dominant trend is the radical transformation of jobs* and occupations and to a lesser extent their replacement by robots, the policy choice is straightforward: by supporting grassroots entrepreneurship and implementing well designed education policies, humans could keep the race between technology and education, and consequently, humans will also have jobs in the future. In academia, Brynjolfsson's (2015) "Open Letter on the Digital Economy", which in the meantime attracted the brightest minds in this field including many Nobel laureates, has raised awareness of the eminent role of education and entrepreneurship. This letter advocates that not only more resources should be devoted to education, it is equally important to focus on creativity and problem-solving skills in education, alongside the STEM subjects that are crucial in the digital economy. Similarly, the *New Skills Agenda for Europe* of the European Commission (2016b) proposes specific measures for improving those skills that are vital today and in the future in order to win the race between technology and education.

2.4 A preliminary review: high degree of uncertainty and divergence of methodology

In contrast to the extensive policy discussions, the emerging research literature, and the rise in public awareness, there is a very *high degree of uncertainty* regarding the impact of robotisation and automation on the labour market (see *Figure 3*). Estimates for replacement of human jobs by robots range from 14 to 50% of all jobs, while those for transformation of

human jobs range between 25 and 60%. These differences can be partly traced back to the distinction between the tasks and the jobs on the one hand, and on the other hand partly to constraints of the data available and the differences in research methodology.

However, the distinction between replacement and transformation is not by any means a purely methodological question. Studies putting replacement in the forefront inherently suggest that we can do nothing about our future and the robots are coming no matter what, and they will ruthlessly take over the jobs currently held by humans. In contrast, studies and reports focusing on the ongoing job polarisation in Europe (Goos et al., 2009; Fernández-Macías, 2012; Amoroso and Moncada-Paternò-Castello, 2018; Sebastian and Biagi, 2018) and the profound transformation of jobs such as the latest report of the European Commission on Artificial Intelligence (Craglia (Ed.), 2018) and the recent annual review on Employment and Social Development in Europe (European Commission, 2018) imply that humans will confront a challenge of manageable magnitude, one for which humans will have to develop appropriate policy responses.

Figure 3: The diversity of policy options according to their initials assumptions, theoretical backgrounds, and research findings

	initial assumption	theoretical background	research findings and estimates
'taxing robots'	robots can take over non-routine complex cognitive tasks	theory of technological unemployment (Keynes)	robots will replace 14 to 50% of human jobs
ownership of robots	price/wage competition between robots and humans	theory of comparative advantages (Ricardo)	the price of robots and the payback period of robots are constantly decreasing
strengthening the comparative advantages of humans	tasks requiring creative and social intelligence will be carried out by humans even in the long term	theory of creative destruction (Schumpeter), and of the race between technology and education (Goldin and Katz)	the dominant process is the transformation of jobs (25-60% of workers will be affected)

A preliminary review also shows that both policy and research efforts are almost exclusively focusing on the *quantitative* side of the potential effects and only to a lesser extent on the *qualitative* one. Whether it comes to replacement or transformation of jobs, it is the potential number of jobs affected that dominates thinking. Nevertheless, the *nature of work* and the *quality of those jobs carried out by humans* are equally important in managing the current technological transformation successfully.

3. Further questions and considerations of the policy options

Each of these policy options raises numerous questions that need further and deeper research.

3.1 The future of employment is not the same as the future of work

Regarding the idea of ‘taxing robots’:

- the starting point—what can be automated will sooner or later be automated—may seem clear-cut, although *technological possibility does not immediately and directly translate into economic reality*, and what is technologically possible is not necessarily feasible or desirable in economic terms (Acemoglu and Restrepo, 2017).
- it is indisputable that the *future of work* is significantly determined by technology, but the *future of employment*, workplaces, and labour standards is also substantially shaped by public policy. The future of occupations and employment is not by any means equal to the future of work determined by technological possibility.
- Jobs and *workplaces are social and economic constructs*, and it is the *entrepreneur* who transforms the innumerable tasks and jobs that could or should be done into workplaces. In addition to this, having a job not only provides a human with a livelihood but also social connections and human communities, and the social significance of jobs in the future may be more important than their direct economic roles (Tirole, 2016).

There is a huge range of studies on the future of work (Balliester and Elsheikhi, 2018) which almost exclusively focus on the potential replacement of human work by robots based on what is technologically possible, but little is known about how the entrepreneurs will capitalise on this opportunity or about the expected dominant trend of the transformation of work and jobs, and even less is known about how humans and robots will co-operate in the work processes in the future.

3.2 Looking at the global context

The second policy response, that of the ownership of robots, also raises further research questions because:

- While it seems to be clear that the price/wage competition between robots and humans could influence the job replacement process, there is very little knowledge about the future prospects of profits that companies might earn by implementing robots (mostly in manufacturing) on the one hand, and on the other hand by employing humans in those activities (supposedly with more value added) that require human creative and social intelligence.
- Similarly, while the future of work and the potential replacement of humans by robots are discussed at great length in the developed countries, little is known about the global consequences of the price/wage competition between robots and humans. In particular, in the *developing countries* that are most likely to be dramatically affected by these changes, and where it is estimated that around *two thirds of all jobs* might be susceptible to automation from a purely technological standpoint (World Bank, 2016). This is because the jobs where even today robots can replace humans were precisely those that have been relocated to developing countries during the course of globalisation. Industrial

statistics shows that the *density of robots* is the highest in the developed world while countries of the emerging markets lag far behind and below the average of 74 multipurpose industrial robots per 10,000 employees in manufacturing industry in 2016 (see *Figure 4*). These figures alone forecast that a large part of jobs previously outsourced to the developing countries may be redundant in the future. As a [European Commission \(2016a\)](#) survey on manufacturing at the firm level has already shown, companies using industrial robots are less likely to relocate production outside Europe. It is true that in the last two decades as a consequence of outsourcing low-skilled jobs from the developed to the developing world, hundreds of millions of people have escaped absolute poverty. In fact, many in the emerging economies have reached the gateway to middle-class prosperity ([Kharas, 2017](#)). However, it is also likely that because of the cruel law of price/wage competition, robotisation and automation may put an end to this trend.

- More than this, it is also likely that the developing world may be left without a feasible convergence model. The traditional model was based on industrialisation driven by imported technology and cheap locally available labour, and as preconditions for that, the opening up of markets, foreign direct investments, and the liberalisation of the economy. However, it seems that this rapid industrialisation peaked in many developed countries by the end of the last decade and came to a halt ([Felipe et al., 2014](#); [Amirapu and Subramanian, 2015](#)). They now have to confront the problem of *premature deindustrialisation* ([Rodrik, 2015](#)) without industrialisation having lifted them out of the group of low-income or lower-middle-income countries, and without the middle class and the transportation and institutional infrastructure having been strengthened, or without public services such as healthcare or education important for the future having been improved. Since robotisation and automation drastically reshape global value chains, as value creation within the chains increasingly shifts towards digital technology, in the developing countries the lack of the necessary human infrastructure, skills, and competences may increasingly block the path towards further convergence.

Figure 4: Robot density in developed world and emerging markets, selected countries, 2016
(number of installed multipurpose industrial robots per 10,000 persons employed in manufacturing industry)

Developed world (list follows the world ranking)		Emerging markets (selected list)	
Republic of Korea	631	China	68
Singapore	488	Thailand	45
Germany	309	Malaysia	34
Japan	303	Mexico	31
Sweden	223	South Africa	28
Denmark	211	Turkey	23
United States	189	Argentina	18
Italy	185	Brazil	10
Belgium	184	Indonesia	5
Taiwan	177	India	3
Spain	160	Philippines	3
Netherlands	153	Russia	3

Source: *International Federation of Robotics, IFR (2017). World Robotics 2017. p. 69-70.*

3.3 What skills do the new jobs need?

The third policy response emphasises the straightening of the comparative advantages of humans, their skills, and competences where robots cannot compete also raises further research challenges:

- Because of the strong research focus on potential replacement of current jobs and on human skills that will be affected, less is known about what skills are needed in the *new jobs* that will emerge and what skills are needed if the transformation of occupations is to succeed. It is definitely much harder to predict the future skill needs than to analyse the skills requirements and the skill gaps of current jobs which are exposed to robotisation and automation. However uncertain it may be, it is badly needed in order to manage a smooth transformation and not to remain a hostage to the replacement idea.
- If using the available data it is hard to predict what future jobs and work will be like due to the rapid technological changes, one of the solutions might be greater involvement of the companies in education and training. As JRC studies show, innovative companies attach very high value to the availability of personnel with knowledge, in particular when deciding the location of R&D (Dosso et al., 2017, Potters et al., 2017). Firms and entrepreneurs are not only drivers of technological changes, but they are also in contact with the market on a daily basis, so they have a better inkling of what skills and competences will be necessary in the years and decades to come. The weak contact between business and education is perhaps one of the reasons why technology has now raced ahead of education.
- Finally, the basic idea that everything can be automated in the future other than the tasks requiring creativity, innovative, critical thinking, problem-solving, cooperative skills, and communication may hold true, although the challenge of how to deal with the situation that *creative and social intelligence are not distributed evenly across society* will definitely remain high.

4. Missing dimensions: time and space

It is true that classic economic rationales are still working in the age of new technologies and with their help potential policy responses could be designed. It seems, however, that these policy options raise numerous questions requiring further and deeper investigation at the current stage of research in order to choose the right policy path. In addition to this, two dimensions—time and space—are almost completely missing in the research literature.

First, robotisation and automation are *time-saving technologies* and similar to other time-saving innovations of previous industrial revolutions, the real economic and social effects not only lie in their direct impact on productivity and employment, but also in the huge amount of time that will be freed up for us. Take the example of the second industrial revolution with its innovations from the washing machine, the microwave and the vacuum cleaner, they all saved so much time for housewives that in the second half of the 20th century women could join the labour force in huge numbers, thereby greatly contributing to growth in GDP and productivity and, more importantly, profoundly transformed the whole of society. Robotisation and automation will have precisely the same time-saving effects, think only of the autonomous car and the estimates that by 2030 driverless cars and digital transportation organisation will have freed up a total of 1,900 billion minutes globally for

long-distance commuters every day (A.T. Kearney, 2016).

Second, robotisation and automation are technologies that will fundamentally reshuffle the territorial structures at global, national, and regional level. At global level they may transform the global value chains as value creation is gradually shifting within the chains towards digital technology, and in parallel with this, value creation is becoming more and more detached from concrete geographical areas. In short, global value chains may become *structurally less complex and more virtual* (De Backer and Flaig, 2017), and the development and operation of long value chains covering the assembly of many parts, several facilities, and many countries around the globe may also become increasingly redundant over time.

At national level, robotisation and automation may create an opportunity for *producing geographically near the consumer market* and metropolitan regions as the complexity of the products diminishes, and production could become unique, small-scale, and tailor-made. In parallel with this, the opportunity for smaller enterprises to create and operate global value chains could arise, the so-called micro-multinationals as well. In other words, due to robotisation and automation the global value chains may become much shorter geographically and structurally 'more democratic'.

Finally, it is the locally and culturally embedded *ecosystem* at regional level that makes robotisation and automation successful. The combination of human and machine intelligence, in particular the application of various technologies connected to robotisation and automation such as 3D printing, Big Data analysis, the Internet of Things, and cloud services, that require a very complex interplay between cooperative partners to develop around the companies comprising universities, R&D institutions, start-ups, incubators, accelerators, venture capital, corporate producers, and digital service providers.

In short, the territorial restructuring at global, national, and regional level posed by robotisation and automation will remain one of the main policy challenges in Europe especially the questions on how to deal with new territorial disparities, and how to achieve a territorially more balanced development in the age of robotisation and automation.

5. Final remarks

While this paper predominately focuses on policy responses to labour market challenges posed by particular technologies—robotisation and automation—the policy options discussed here in a wider sense are *relevant to every technological transformation*. First, the policy option of taxing robots (i.e., taxing capital) and introducing a basic income via *redistribution of the benefits* aims to compensate those who are disproportionately negatively affected by technological transformation. The second policy response of ownership of robots emphasises the question of how can *access to the benefits and utilisation* of technological transformation among different groups in the society be increased as widely as possible. The third policy alternative highlights the improvement of human skills that the robots will never be able to match is centred on *individual adaptation and institutional adjustment* to the technological transformation. Therefore, the lessons that are drawn from the current discussion of policy options driven by specific technologies, robotisation, and automation might serve as a precursor for potential policy responses also triggered by other technologies.

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