4

In Favour of Machines (But Not Forgetting the Workers): Some Considerations on the Fourth Industrial Revolution

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Introduction

We are in the middle of what many call the Fourth Industrial Revolution (4IR). We have some idea of when and where it started, but there is still much debate about how long it will take to deliver all of the promised fruits to the economy and society. Many scholars and observers foresee a hypothetical future of jobless economies, where machines could perform not only most of the physical activities now carried out by humans but also a large part of intelligent human activities.

In these future scenarios that oscillate between utopia and dystopia, one wonders what should be done to allow everyone to benefit from the fruits of automation and the well-being promised by machines and artificial intelligence (AI). At the moment, however, of this future world that

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E. Ales et al. (eds.), *Working in Digital and Smart Organizations*,
https://doi.org/10.1007/978-3-319-77329-2_4

creates wealth without human labour, we see very little, and hopefully a future of mass technological unemployment will never see the light of day.

Instead, what we have been witnessing for quite a long time are profound transformations in technology, products and production processes and, related to this, in the nature of labour and demand for skills, in the distribution of job opportunities across sectors and territories, in labour relations and in wages.

These changes create great opportunities for some but also inequalities and uncertainty for many, at least in the short to medium term. Since few seem to doubt the benefits of technology and scientific progress, the 4IR should be accompanied by policies that encourage progress but at the same time limit the negative consequences on labour, income, and quality of life. However, although there are many policies in favour of technology and machines promoted by governments in many advanced countries, far fewer, and less effective, are the policies that deal with labour and workers who are fully invested by the technological transformation in this difficult, and probably long, transitional phase of the new industrial revolution.

The aim of this paper is to give a brief account of some of the main issues related to the 4IR. We start by looking for an appropriate definition of it, in order to identify the conceptual boundaries of the phenomenon, a crucial step for assessing the policies and their impact on the economy. Second, we discuss the impact of the 4IR on employment by reviewing the results of the relevant literature, drawing some lessons for future research. Third, we review some of the industrial policies developed by governments to support the digital revolution. We finish the paper with a discussion of the main policy issues related to the workers and the labour market.

A New Industrial Revolution?

As the founder and executive chairman of the World Economic Forum (WEF), Klaus Schwab, puts it, "*we stand on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to* *one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before*" (Foreign Affairs Dec. 12, 2015).

Many economists, observers, industry experts and technology analysts hold a similar view. Manufacturing, in particular, is radically reshaping production processes and has a strong impact on the use of labour, the nature of work, and the geography of production. This new era of technological change is certainly opening up new opportunities of value creation and growth with innovative products and services but also is disrupting industries and sectors, causing growing social insecurity and new inequalities. The economic and social consequences of this are still unclear and hardly predictable.

But can what has been happening in the last two decades be labelled the Fourth Industrial Revolution? There is a general agreement among historians and other social scientists about the characteristics and consequences of the first three industrial revolutions.[1] All three revolutions had a strong and positive impact on the economy, at least in the long run, in terms of gross domestic product (GDP), employment, productivity, new industries and products. Can we draw the same implications for this new phase of technological change? If indeed we are in the middle of the 4IR, what is the technology or the fundamental innovation that triggered this new historical phase?

Many definitions of this new industrial revolution have been given, some are more convincing than others, many are converging to the same point, but there is still much confusion and a lot of noise and this is due in part to the role played by governments and political interests. The following is a brief survey of the most reliable definitions.

One of the first documents that clearly mentioned the new industrial revolution was a final report published in 2013 by a German working group, named *Plattform Industrie 4.0*, set up and coordinated by the federal government in Germany as part of its ambitious new industrial policy in manufacturing (*High Tech Strategy*). The working group was composed of academics, technical experts, and members from the federal government, industry, professional associations and unions. They coined the term *Industrie 4.0*,[2] which soon after became very popular worldwide. In this document, the 4IR or *Industrie 4.0* is defined as "the technical integration of Cyber-Physical Production Systems (CPS) into manufacturing and logistics and the use of the Internet of Things and Services in industrial processes" (Kagermann et al. 2013, p. 14).

Other influential definitions were later proposed: "Cyber-physical production based on the internet of things and services" (MIT Industrial Performance Center 2017, p. 2), "Digital transformation of industrial production" (OECD 2016, p. 14), "Digitalisation of manufacturing" (IfM-UNIDO 2017, p. 10) and "Application of digital technologies to the manufacturing sector" (European House-Ambrosetti 2017, p. 1).

All of these definitions are focused on manufacturing, and the digital revolution is at the heart of the technological change. The term "digital" does not actually refer to a single technology but to a bundle of *enabling* (and potentially disruptive) technologies which in some cases includes new materials. According to the definition used by the European Commission, "The Fourth Industrial Revolution […] integrates cyber-physical systems and the Internet of Things, big data and cloud computing, robotics, artificial-intelligence based systems and additive manufacturing". The OECD speaks of a "confluence of technologies ranging from a variety of digital technologies (e.g. 3D printing, Internet of Things, advanced robotics) to new materials (e.g. bio- or nano-based) to new processes (e.g. data driven production, artificial intelligence, synthetic biology)" (OECD 2016, p. 3). The Cambridge Institute for Manufacturing speaks of "connection and integration of manufacturing systems through the convergence of digital technologies such as cyber-physical systems, cloud computing, big data, artificial intelligence, machine learning and the internet-of-things" (IfM-UNIDO 2017, p. 26).

Other, related terms are often used to describe this new era of technological development, again with a strong focus on manufacturing: "Next Production Revolution", "Smart Industry", "Smart factory or advanced manufacturing", "Industrial Internet", "Cyber-physical systems" and "AI (Artificial Intelligence)-driven automation" (OECD 2017).

Manufacturing certainly remains at the heart of the 4IR. The emphasis on manufacturing, however, is reductive. The spread of digital technology is equally revolutionizing many service sectors. Digital technologies are embedded in an increasing number of services, and digital platforms and social networks are increasingly used to favour the interactions between economic agents and between individuals. This gives rise to the creation of new sectors of activity—think of music consumption through streaming—and the radical transformation of traditional services, as in the case of commercial distribution, finance and banking, travel agencies or the taxi sector. The impact of the digital revolution on employment and business models is probably stronger in the service sector compared with manufacturing. For example, of all the occupations in the US with the highest probability of computerization listed by Frey and Osborne (2013), only 25.6% of them are related to manufacturing. According to a survey by the WEF, more than 7 million jobs will be lost in a sample of advanced countries in the period of 2015–2020 (WEF 2016); 22.4% of the total loss will be in manufacturing and production, while 66.4% will be in office and administration. In the case of Italy, the report by European House-Ambrosetti (2017) predicts that only 26% of the expected job loss in the next fifteen years will occur in manufacturing. These data suggest that the 4IR should be considered in a broader sense, encompassing all sectors of activity.

Evidence of Displacement? Lessons from the Data

The reduction in manufacturing employment is a long-standing feature of advanced economies. In the last 15 years (2000–2015), the US lost 28.6% of employment in manufacturing, Europe (15 countries) 18.6% and Japan 14.2%.[3] Clearly, robots and automation are only some of the factors that can explain this decline. The rise of China and other emerging economies as the new factories of the world changed the geography of production on a global level in the last decades. Outsourcing and offshoring activities, along with the related increase in imports within global value chains governed by large and small multinationals, have been largely discussed in the literature and are partly responsible for the change. In addition, many technical, office and administrative activities, traditionally carried out in manufacturing companies, have been progressively moved and decentralized in the tertiary sector. Parallel to the decline in manufacturing jobs, employment in professional, technical, administrative and business support services has steadily increased.

A recent report by the OECD shows that, since 2000, almost 29 million jobs have been created in OECD countries, compared with a loss of 750,000 jobs. Even in Europe (EU28), where the labour market is traditionally more rigid, more than 9.5 million people gained a job while almost 3.1 million workers lost employment (OECD 2017). Most of the increase occurred in high-skilled service sectors (professional, scientific, technical, administrative and business support activities) and other service industries such as health and education, wholesale and retail trade, and accommodation and food service activities. At the same time, manufacturing lost more than 5.5 million jobs in Europe.

Industrial robots are employed mainly in the manufacturing industry.[4] As shown by the annual report by the International Federation of Robotics (IFR 2017, p. 87), most of them are used in the automotive industry and in the electrical and electronics industry, although the relative intensity varies across countries.

In contrast, digital (information and communication technology [ICT]) capital plays a limited role in manufacturing but accounts for a substantial share of fixed capital in the information and communication sector, in the business service sector (law and accountancy, research and development, and other business services), in the finance and insurance industry, and in the wholesale and retail trade (EU-KLEMS data).

The picture sketched above has been variously interpreted. The potential impact of the 4IR on the labour market is the subject of a recent and growing literature. The debate is addressing a number of issues, such as the employment impact, the quality of work and skills demand, the dynamics of productivity and its effect on economic growth, and the distribution of income. On the employment issue, in particular, several economists have recently tried to estimate the impact of the digital revolution and AI on employment levels.

A first strand of studies focuses on the characteristics of the different jobs and tasks and, for each of them, tries to predict the degree of potential automation and therefore the probability of job displacement. The first contribution of this type is due to Frey and Osborne (2013), who estimated the probability of computerization for 702 detailed occupations in the US. The conclusion is dire: about 47% of American employees are likely to lose their jobs in the next few years. In their approach, it is assumed that each task at risk of automation corresponds to an entire workplace (*occupation-based* approach).

Less disturbing results are obtained by Arntz et al. (2016), who estimated the job automatibility for 21 OECD countries by using the Programme for the International Assessment of Adult Competencies (PIAAC) database. From the study, it emerges that an average of only 9% of the jobs would be at risk. The difference with the previous paper lies in the distinction between tasks and jobs. Even if some tasks are automated, the worker may remain essential for other tasks (*task-based* approach). With a similar approach, Berriman and Hawksworth (2017) find that up to 30% of jobs in the UK and up to 38% in the US are at high risk of automation by 2030. By adapting the methodology proposed by Frey and Osborne (2013) to the Italian data, the study by European House-Ambrosetti (2017) finds that 14.9% of jobs, roughly equal to 3.2 million workers, are likely to be replaced by machines in the next 15 years.

Another strand of studies tries to study the impact of automation on jobs by using historical and disaggregated data at regional level. In this case, the focus is on manufacturing and on robot exposure.

Acemoglu and Restrepo (2017) focus on the effects of industrial robots on jobs and wages in US local labour markets from 1990 to 2007. They distinguish the impact of robots from other factors potentially affecting employment, such as imports from manufacturing countries (China and Mexico), offshoring activities, and information technology (IT) capital. They find evidence of a significant displacement effect due to the introduction of robots in the period under analysis. In particular, their estimate of job loss is up to 670,000 employees, roughly 6.2 jobs lost (on average) for every robot introduced.

More encouraging results come from a recent study by Dauth et al. (2017). By following an approach similar to that of Acemoglu and Rastrepo, they study the impact of rising robot exposure on the equilibrium across industries and local labour markets in Germany over the period of 1994–2014. They estimate that, on average, every robot destroys two manufacturing jobs, significantly less than found by Acemoglu and Restrepo for the US, for a total loss of 275,000 German manufacturing jobs in the reference period. More interestingly, they found that this reduction in employment was fully compensated by additional jobs in the service sector of the economy. The conclusion is that robots mainly affect the composition of aggregate employment. Interestingly, the results also show that incumbent manufacturing workers are not at risk of displacement, although they have to accept lower wages in order to keep their jobs. The decline of employment in manufacturing observed in stylized data is basically driven by fewer new job opportunities for young people.

Graetz and Michaels (2015) studied the economic impact of robot density in 17 advanced countries in the period of 1993–2007. In the paper, data are collected at the country-industry level. On average, they find no evidence of adverse employment effects due to robot densification. However, technology seems to affect workers according to their skill levels. Robots are associated with a decrease in the number of hours worked by low-skilled and, partially, by middle-skilled workers, whereas the hours worked by high-skilled workers increased during the period, confirming the skill-biased nature of the technological change in the digital revolution emphasized in the literature (Acemoglu and Autor 2011, Autor and Dorn 2013).

Gregory et al. (2016) analyse the effect of routing-replacing technological change (RRTC) on absolute labour demand. Data are collected for 238 regions across 27 European countries in the period of 1999–2010. In their analysis, they take into account three channels through which technology may affect labour. These are substitution effects, product demand effects, and product demand spillovers. The last two effects are expected to compensate for the negative impact of the substitution of capital for labour in routine production tasks. The authors find a positive total labour demand effect of RRTC. Up to 11.6 million jobs have been created across Europe in the reference period.

The evidence provided by these studies is clearly not conclusive. Results vary enormously according to the methodology employed, the availability of data, or the country under analysis. Predictions about the future impact of automation seem to be particularly demanding (and it is not clear which time span is appropriate for assessing the impact of the 4IR on employment and growth). As Mokyr et al. (2015) have pointed out, "discussions of how technology may affect labour demand are often focused on existing jobs […] but offer much less insight about the emergence of as-yet-nonexistent occupations of the future" (p. 45). To have an idea, the introduction of the personal computer in the 1980s gave rise to the creation of more than 1,500 new professions in the US labour market, such as computer programmers, web designers, and data communications technicians (OECD 2016, p. 13). These job titles were simply unthinkable before the development of the new technology. Given these considerations, perhaps it is wiser to follow Dany Rodrik's advice: making predictions is not and should not be among the economist's tasks (Rodrik 2015). However, from this literature, we can learn a number of lessons that can be useful for future research.

First, at an empirical level, it is not easy to estimate the impact of the 4IR on the labour market. How is one to measure the extent of technological change? What is the best measure to capture the basic features of the digital revolution? As we have seen, the digital revolution is associated not with a single technology but with a bundle of many enabling technologies. By automating tasks previously performed by humans, robots can clearly displace jobs. But physical robots, such as those classified by the IFR and used mainly in manufacturing plants, are just one type of job-displacing technology. "Software" robots (*Financial Times* 2017) can equally have a tremendous impact on jobs, especially white-collar jobs, in both the manufacturing and service industries. Indeed, this was the case in the last decades since the diffusion of the ICTs. So investments in ICT computing and communications equipment plus related investments in software and databases can be another useful proxy for the digital revolution.

The point is that in many (service) sectors where ICT intensity is high, employment did not decline. This suggests that although many jobs have been displaced by ICT and software, many others have been created, compensating job losses with new opportunities of employment. As emphasized by Autor (2015), automation substitutes labour, but strong complementarities between automation and labour occur that increase productivity, raise earnings, and augment demand for labour. "Technology eliminates jobs, not work".

All this suggests that focusing on manufacturing and industrial robots can be reductive. It is necessary to adopt a general equilibrium approach because compensating forces can act across different sectors of the economy.

Second, robots and ICT capital are strictly supply-side variables, but there are other more general indicators that could be employed in empirical analysis in order to assess the extent and progress of the digital revolution, particularly in cross-country comparisons. Some examples are the fixed and mobile broadband penetration, the number of internet users, the number of patents in AI technologies, research and development indicators, human-capital indicators, and quantity and quality of scientific publications (OECD 2017). These variables can be useful not only for assessing the extent of the digital revolution but also, more importantly, for evaluating the potential for innovation. This is very important because the innovative capacity of a country is crucial for the creation of new industries and services and therefore for new jobs in the future.

Third, technological change and digitalization interact with institutional and structural factors. Structural weaknesses and rigidities of each country can make the adjustment more difficult and slow. For example, the impact of robots depends on the importance of manufacturing in the economy and its industry composition. Also, the size distribution of firms matters since large firms are more likely to innovate and digitalize production (OECD 2017). Institutional arrangements, particularly in the labour market, can also affect the path and speed of the digital revolution. For example, co-determination by workers and management is a guiding principle of German corporate governance. This might explain why in Germany the diffusion of robots and digital technologies is associated with a minor loss of manufacturing employment compared with other countries.

In summary, although the 4IR started two decades ago, some of its more disrupting technologies are still far from spreading extensively across sectors and countries. Stylized data show that although the introduction of the new digital technologies is having a deep impact on some sectors and industries, its overall effect on employment has so far been fairly limited. With wide variations between countries, new opportunities of jobs in dynamic service sectors more than compensated for the loss of jobs in manufacturing.

In Favour of Machines: Policies for the Future of Manufacturing

Industry 4.0 is a very popular term in the political discourse.[5] The Germans invented it and Chancellor Angela Merkel refers to it as *"the comprehensive transformation of the whole sphere of industrial production through the merging of digital technology and the internet with conventional industry"* (Federal Government 2014). This is not just a formal recognition of a new technological revolution; it is the starting point of new industrial policies aimed at revitalizing the manufacturing sector and strengthening its competitiveness. *Plattform Industrie 4.0*, which was launched by the German government in 2011 as a part of High Tech 2020 Strategy, is the first national policy explicitly addressed at supporting digital manufacturing. Its aim is to promote the integration of CPS and Internet of Things and Services (IoTS) in the manufacturing sector (European Commission 2017). The platform does not provide direct incentives to invest in digitization, but it draws up recommendations for actions through dialogue with all of the relevant stakeholders (businesses, trade unions, science and government). It also promotes, finances and supports research, projects, and test beds carried out by companies and specialized technology centres at universities and research institutions.

Starting with Germany, almost every advanced country has developed policies and strategies to promote technological change and support the diffusion of digital technologies. There are plenty of examples, not only in Europe but also in the US, China and Japan. A detailed review of these policies is outside the scope of this work.[6] However, it is useful to highlight some general characteristics of these initiatives.

Some policies are truly consistent with the above-mentioned definitions of the 4IR; some have definitely broader goals, which have a more tenuous relation to the digital economy; others, because of the limited resources mobilized by the governments, seem just political slogans with little content and impact.

In Europe, there are basically two types of policies. The first is aimed directly at companies, with the aim of encouraging the adoption and diffusion of digital technologies in the production process. The main objective is to foster private investments that can allow companies to reap the benefits of the 4IR in order to revitalize manufacturing and make it more competitive.

The instruments are those typical of incentive policies, such as subsidized loans, tax credits, and amortization schemes. This type of policy requires strong financial support from the state. An example is *Industrie du Futur*, launched by France in 2015, to which about 10 billion euros has been allocated (European Commission 2017). The French government has recently strengthened its intervention with the *Gran Plan d'Investissement*, which earmarks 4.9 billion euros in the period of 2018–2022 to support investments in some key digital technologies and a further 9.3 billion euros to accelerate the digital transformation of public services and health.

Along similar lines, the *Industria 4.0* initiative, launched by the Italian government in 2016, provides tax incentives and other measures to support digital innovation. The estimated total cost of the program is 18 billion euros until 2020 (European Commission 2017, MISE 2017).

In the second type of policy, public support is directed mainly at providing services, allowing knowledge sharing and awareness, and financing innovative research projects for the digital transformation of production processes. Examples are *Industria Conectada 4.0* in Spain and *MADE* (Manufacturing Academy of Denmark) in Denmark, both launched in 2014.

Other countries implemented policies with a broader goal. In the UK, the *High Value Manufacturing (HVM) Catapult initiative*, which started in 2011, is basically focused on supporting innovation through the creation of a network of technology centres (UK Government 2013). However, only one of these centres is dedicated to digital technologies. *Produktion 2030* in Sweden and *Smart Industry* in the Netherlands have a similar nature but with limited funding from the state (European Commission 2017).

The active role of governments in the 4IR is a new and important factor, a strong difference with the first three industrial revolutions in which policy apparently played a limited or indirect role. By supporting the digital revolution, all governments (implicitly) believe that the 4IR will be beneficial to the economy (GDP growth, productivity, exports, and competitiveness) and society (employment, quality of life, environment, and income distribution), at least in the long run.

To quote the title of the famous book by Brynjolfsson and McAfee (2011), no government seems to be involved in "the race against machines". All are in favour of this new wave of machines and technological progress. This general optimism of governments seems to be confirmed by the last Eurobarometer survey sponsored by the European Commission (Eurobarometer 2017) and carried out in 28 member states. According to the results, more than 60% of respondents have a positive view of robots and AI. However, an even larger proportion of respondents (72%) think that robots and AI are stealing people's jobs.

Policies in favour of machines and product innovations in manufacturing (such as Industry 4.0) are usually widely accepted and politically sustainable. There is a substantial uniformity of pro-technology policies among advanced countries though with differences in the modalities and intensity of public support. Even when machines clearly substitute for labour, there seems to be no inclination towards Luddite-type ideas or practices. Trade unions and leftist parties strongly oppose the outsourcing of production as well as imports of low-cost goods due to social dumping—two of the main factors held responsible for the loss of employment in manufacturing in advanced countries. However, their attitude towards automation and technological change is much more cautious and for some good reasons.

First, although manufacturing employment is stagnant or declining in many advanced countries, manufacturing plays a crucial role for exports, research and development, innovation, and the productivity of a country. Robots and AI promise to make production and firms more efficient, a necessary step to regain competitiveness in international markets and preserve employment. This is particularly true for small to medium enterprises (SMEs), which play a relevant role in many advanced economies and often need technological upgrading.

Second, robots and AI can be complementary to labour ("co-bots") and can contribute to better working conditions. By replacing many repetitive and dangerous tasks, they contribute to increase the demand for more skilled workers, increasing the opportunities for re-training and professional advancement.

Third, there is a hope that robots can help the re-shoring of many manufacturing activities outsourced to low-cost countries in the last decades. However, this issue is highly controversial, as the debate on the new tax bill of the Trump administration clearly shows. Furthermore, this hope does not take into account that at the moment China is the country with the highest rate of growth in robot adoption.

In Europe, this positive attitude towards robots and AI is also influenced by the widespread conviction that observed unemployment (particularly in the countries of Southern Europe), much more than technological innovation, derives from the lack of coordinated anti-cyclical policies, fragility (if not absence) of industrial policies, etc. On the supply side, in these countries, what (if anything) is feared is a delay in the adoption of new technologies and not a too rapid run towards them. The debate on the low rate of productivity growth in Italy since the second half of the nineties is a paradigmatic case.

Hence, in many advanced countries and not only in the US, there is a serious risk of over-consensus towards policies that univocally tend to favour capital over labour. As Acemoglu observes, "We are creating huge subsidies […] for capital and encouraging employers to use machines instead of labor" (Acemoglu, quoted in *Newsweek*, February 2018 and in Arnold 2017, Goodkind 2017).

To this regard and for various reasons, there is a marked difference between the manufacturing and the service sectors in the political consensus granted to the digital revolution by employers, workers, unions, and political actors. The resistance to a massive adoption of digital technologies seems to be stronger in the service sector than in industry. New (or potential) Luddites are certainly far more common among taxi drivers than they are in industrial workshops, as the past violent protests against Uber in Paris, Rome, Johannesburg, and many other cities all over the world have clearly shown. Widespread discontent and protests are also common among hotel workers and hoteliers against Airbnb and Booking.com, or independent bookstores against Amazon. More generally, while there is a broad consensus on the need to regulate these new economic activities based on internet and digital technologies, there is no agreement on the specific measures to be taken. It is difficult to find balance between policies in favour of competition and protection of workers' rights, and the outcome can be an illegitimate defence of rent positions. Until now, governments, local administrations, and regulatory agencies proceed on their own, often with hesitation and difficulties. While *Industry 4.0-type* policies are common to all advanced countries, policies in favour of the diffusion of digital technologies in the service sector are more fragmented and difficult to implement. An example is the public administration, where the digital transformation of public services and the dematerialization of processes through the use of digital technologies are very slow in many countries, with a pace often conditioned by the problem of generational turnover and workers' resistance.

Not Forgetting the Workers: Policy Issues

John Maynard Keynes predicted widespread technological unemployment "due to our discovery of means of economising the use of labour outrunning the pace at which we can find new uses for labour" (Keynes 1963, p. 3). In *Economic Possibilities for Our Grandchildren* (1930), he envisaged a world with no scarcity, short working hours and plenty of leisure. More recently, in the same mood, Brynjolfsson spoke of a "Digital Athens", in which robot slaves can produce all the necessary goods, leaving people time for leisure, sport, arts and entertainment. However, a Digital Athens requires radical policies.

A strand of the contemporary policy debate takes very seriously the potential for labour substitution of robots and digital technologies and tries to find policy solutions that can solve the problem at the root. Among these, a robot tax, shared robot ownership, and universal basic income (UBI) are some of the most attractive proposals.

In her draft report to the European Parliament on civil law rules in robotics, Mady Delvaux, Member of the European Parliament and member of the Committee on Legal Affairs, suggested that "the possible need to introduce corporate reporting requirements on the extent and proportion of the contribution of robotics and AI to the economic results of a company for the *purpose of taxation* and social security contributions". She added that "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" [emphasis added] (European Parliament 2017). Although in the final resolution the European Parliament rejected these proposals, the example testifies to the increasing attention that politicians, economists, and public opinion are dedicating to the issue of a robot tax and UBI.

The issue of taxing robots for the purpose of collecting resources to pay for the transition costs caused by disrupting technologies is highly controversial (Guerreiro et al. 2017). Bill Gates was one of the first to support the idea: "If a human worker does $50,000 of work in a factory, that income is taxed. If a robot comes in to do the same thing, you'd think we'd tax the robot at a similar level" (see interview with *Quartz* , Delany 2017). A moderate and temporary tax on robots was advocated by Nobel Prize laureate Robert Shiller (2017) with the aim of slowing down the pace of the diffusion of robots and the substitution of labour. The main argument is that this tax, as part of a broader policy to support and retrain displaced workers, not only is socially just, because the revenues can be used to address inequality and compensate for the negative externalities of robotization, but also can be more politically acceptable compared with other measures, such as UBI or a more progressive income tax.

A recent paper by two law scholars, Abbott and Bogenschneider (2018), argues strongly in favour of a mix of policy measures, including an "automation tax", with the aim to achieve "tax neutrality" between human workers and robots. The main point is that existing tax systems are designed to tax labour more than capital. This encourages firms to invest in robots and other labour-substituting technologies even when this choice is not justified by efficiency considerations. The effect is not only a loss of employment but also a potential significant reduction in revenues for the government given that most tax revenues come from workers. As the authors say, "robots are not good taxpayers". The concern about revenue loss is reinforced by the fact that the promised benefits of automation and AI in terms of productivity growth and new employment are yet to come in many advanced countries.

As we have seen earlier, many policies inspired by *Industrie 4.0* use tax and fiscal incentives to promote investments in robots and digital technologies. To avoid excessive automation, these policies should be counterbalanced by effective incentives for hiring and training workers.

However, most economists are rather lukewarm if not openly hostile to the robot tax. Many think that this proposal would have undesirable consequences. One argument is that this measure is very difficult to apply in reality. It implies a clear identification of robots that generate unemployment. Although the recommendation to grant robots a legal status advanced by the European Parliament can go in this direction, many labour-substituting digital technologies, such as so-called software robots, are even more difficult to identify. This problem of identification would give rise to a high number of legal battles and controversies.

Another point is that robots and digital technologies are not the only factors causing unemployment. Many new products or technologies can cause substantial reductions of employment in specific industries, but nobody can really think of discouraging innovation or slowing it down through fiscal policies. Lawrence Summers labelled the robot tax "a form of protectionism against progress" (*Financial Times*, March 5, 2017). The tax would have the effect of discouraging the production and the diffusion of robots, preventing not only the positive effects on productivity and growth but also the development of better products and services. Not surprisingly, similar arguments have been put forward by the IFR, the association of robot producers (IFR 2017).

Lastly, to be effective, a tax on robots should be applied on a global level; otherwise, production and investments would move to other countries with a more favourable legislation or offshore.

A variant of the robot tax is the sharing of ownership of technological assets. This idea has been advocated mainly by Freeman (Freeman 2015, see also Berg et al. 2016). The capital share is a basic determinant of income distribution. The evidence shows that this share has been steadily increasing in the last decades. Robots would drive up the capital share indefinitely, so the income distribution would tend to grow ever more uneven. The risk, however far in time, is to arrive at a situation of great inequality, called by Freeman "modern feudalism", in which a few billionaires, like the old feudal lords, possess all the wealth and dominate both the markets and the governments—definitely a scary future. The only way for workers to benefit from labour-substituting technology is *by owning* part of the capital that replaces them. As Freeman puts it, "we must earn a substantial part of our incomes from capital ownership rather than from working". The idea sounds good. However, how to realize it without major social upheavals is another story.

As we have seen, the idea of the robot tax has several weaknesses that make its practical applicability quite difficult. Another idea, which is becoming increasingly popular and which appears, albeit in questionable versions, in the political debate of some countries, is UBI for all citizens, regardless of their economic condition. According to the definition given by the BIEN (Basic Income Earth Network), the organization founded in 1986 that collects the network of supporters of the idea worldwide, “A basic income is a periodic cash payment unconditionally delivered to all on an individual basis, without means-test or work requirement”.

This idea, even more radical than the tax on robots, tries to provide an overall response to the two phenomena that have characterized advanced societies in recent decades: the increasing inequalities and the increasing polarization between a small number of owners of capital and high-skilled workers and the vast majority of people with low wages and precarious jobs.

The basic idea is the following. If highly productive machines are destined to replace much of the work in the future, this on the one hand will result in a growing concentration of wealth in the hands of those who own the machines or the high skills necessary for the development of technologies. On the other hand, it will squeeze the income and wages of the majority of the population that would work less or find work, at low wages, in activities that cannot be substituted by machines. With falling wages, many people may not have sufficient resources to meet their material needs. Moreover, low incomes could cause problems of aggregate demand because the large amount of goods produced by robots and intelligent machines is likely to remain unsold. Provision by the government of a guaranteed basic income would allow everyone to have enough resources to be able to purchase goods and services necessary to live in dignity (basic necessities). It could also allow people to freely choose whether to work and what kind of work to do (e.g. by rejecting particularly under-skilled or under-paid jobs).

Clearly, the proposal, and the future scenario on which it is based, is very strong. The idea is not new and has appeared several times in the economic debate, albeit with different motivations (a documented review is contained in the BIEN website and in the book by Standing 2017). Milton Friedman, for example, advocated basic income in the form of a negative income tax from an ultra-liberal perspective as an alternative to the welfare system and to reduce the intervention of the state in the economy.

The idea of some form of universal income is supported by some economists and social scientists (Robert Reich, Van Parijs and Guy Standing), by a growing number of politicians, mainly from the left (Bennie Sanders, Jeremy Corbyn and Benoit Hamon), and by some important technology entrepreneurs, such as Elon Musk of Tesla and Facebook CEO Mark Zuckerberg.

Van Parijs and Vanderborght (2017) and Guy Standing (2017) are some of the most fervent supporters, though on the more general grounds of "social justice, freedom and security" rather than as a solution to a future of technological employment.

Attempts to apply the idea are not lacking. In June 2016, Switzerland held a referendum on the introduction of basic income for all, but the proposal was rejected by 77% of voters. In January 2017, the government of Finland launched a trial of a form of unconditional basic income, but the experiment is limited to 2,000 unemployed people. In January 2018, the Council of Europe (2018) adopted a resolution in favour of the UBI containing generic recommendations to the European Member States. Other cases of experimentation are cited for Canada, the Netherlands and some developing countries. However, these experiments have different aims and are crucially limited to specific target groups. They cannot be taken as evidence of application of UBI.

As with the robot tax, however, the reaction of most economists is generally negative. This proposal not only is very burdensome for the state but also could be insufficient to guarantee some basic goods and services to everybody, such as health and education (McAfee and Brynjolfsson 2016; Colin and Palier 2015). In principle, it could be financed by dismantling the welfare state—but this solution is politically unsustainable, especially in European countries, which are based on an extensive and well-established welfare system (Meyer 2016)—or by a strong redistribution of the income gained by the owners of the machines.

McAfee and Brynjolfsson (2016, p. 147) argue that we are not yet in a jobless economy and the programmes for UBI would be too expensive to sustain and difficult to manage. Instead, policy "should encourage employment" basically with wage subsidies. In this way, workers are incentivized to work more hours.

In a recent forum organized by the review *Intereconomics*, several economists shared their view on the topic (Intereconomics 2017). The forum concludes dryly that "no serious answers have been found to the a question of how to finance such a system, and until a workable solution is found, a UBI is simply not feasible".

Given these difficulties, some political proposals try to limit the application of the measure to specific target groups (unemployed workers, low-income families, and disadvantaged people). However, these social problems can probably be better managed with existing policy measures. If the application of UBI is not universal, it is not clear how it can address the problem of increasing mass technological unemployment.

From a different perspective, another argument against UBI is linked to the social and cultural value attributed to the work activity per se, the ethics of work. The concern is that such a measure could discourage human work and discourage active job creation policies and have profoundly negative social consequences. McAfee and Brynjolfsson (2016): "declining work-force participation is troubling not only because work provides income but also because it gives people meaning". However, from a wider perspective, this argument is highly controversial. Post-work ideas that claim the positive values of leisure are gaining ground among politicians, unions and social activists (see the interesting survey by Beckett 2018).

The theoretical debate and policy proposals discussed so far are certainly very interesting and in some ways provocative. However, the impression remains that they are rather surreal. We are still very far from a future in which machines do everything and perhaps this will never happen. A recent article in *The Economist* reports the results of a survey among high-qualified attendees at two AI conferences (*Economist*, 1 November 2017). One of the questions was about the predicted year in which all labour would be fully automated—a gloomy future of human obsolescence. The researchers thought that it would take, on average, 125 years. The most "optimistic" were the Asian researchers, who indicated 104 years, much earlier than the Americans, who thought, on average, 169 years. The most "pessimistic" researchers responded not less than 200 years. The aspect to be understood is that the 4IR is still far from being completed and this transition period will probably last a long time and entail different times and speeds from country to country. The transition period, however, is not painless.

The digital revolution brings about radical changes and disruptions. Employed workers, economic activities and existing companies (incumbents) feel increasingly threatened. The labour market, in particular, is deeply affected. It is more difficult to find a job for low-skilled workers and for young people. Stable jobs are no longer the norm for new entrants in the labour market, and the number of temporary jobs is increasing in many countries, particularly for young people. For many workers, real wages are declining.

Policies are increasingly called for to accompany this period of transition and to mitigate the negative effects of the digital revolution. However, although it is easy to find policies in favour of the machines, few policies so far have effectively addressed "the painfulness of readjustment between one economic period and another", as Keynes put it (1930). This is the most difficult and compelling challenge facing the advanced economies. In past industrial revolutions, politics had been substantially absent. Now governments cannot stand by, and the debate about what needs to be done is entirely open. What are most needed are new policies, designed for this new era of technological change while avoiding the temptation to revive forms of protection and regulation designed for an out-dated industrial age. The design of policies in favour of work is made even more complex by the fact that many workers in the digital economy present specific characteristics: they are neither employees nor contractors. They are "independent workers". They should enjoy some forms of protection and benefits, typical of the employees, but still retain independence and flexibility. Existing labour regulations are ill equipped to understand these new forms of employment. However, actual experiences are dramatically few while social costs are growing day by day.

Notes

1. The first was characterized by mechanical production facilities and began in Britain in the 1780s with the help of water and steam power. The second introduced and developed mass production with the help of electrical energy, particularly in the early twentieth century. The third began in the 1970s and was characterized by the use of electronic and IT systems that further automated production.
2. The term *Industrie 4.0* was used for the first time during the 2011 Hannover Fair (Schwab 2016).
3. Our computation based on EU-KLEMS, OECD-STAN and BLS data.

4. An industrial robot can be defined as “an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications” (IFR 2017, p. 32).
5. Also, “smart” is very popular. It is so popular that recently the EU, with perhaps excessive emphasis, labelled a programme Smart Anything *Everywhere* (SAE)!
6. A recent survey can be found in European Commission (2017).

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