http://doi.org/10.20336/rbs.806

REVISTA BRASILEIRA DE SOCIOLOGIA

Technology as enabler of the automation of work? *Current societal challenges for a future perspective of work*

A tecnologia como facilitadora da automação do trabalho? *Desafios sociais atuais para uma visão do futuro do trabalho*

Bettina-Johanna Krings*
António B. Moniz**
Philipp Frey***

ABSTRACT

Due to the innovative possibilities of digital technologies, the issue of increasing automation is once again on the agenda – and not only in the industry, but also in other branches and sectors of contemporary societies. Although public and scientific discussions about automation seem to raise relevant questions of the "old" debate, such as the replacement of human labor by introducing new technologies, the authors focus here on the new contextual quality of these questions. The debate should rethink the relationship between technology and work with regard to quantitative and qualitative changes in work. In this article, our example will be the introduction of automation in industry, which has been reflected in the widely recognized study by Frey and Osborne in 2013. They estimated the expected impacts of future computerization on US labor market outcomes as very high, specifically regarding the number of jobs at risk. Surprisingly, this study was the starting point of an intensive international debate on the impact of technologies on the future of work and the role of technological change in working environments. Thus, according to the authors, "old" questions remain important, but they should be reinterpreted for "new" societal demands and expectations of future models of work.

Keywords: automation, technical unemployment, transformation of work, new models of work.

* Doctor in Sociology, Senior Scientist at the Karlsruher Institut für Technologie (Institute for Technology Assessment and Systems Analysis) Karlsruhe, Baden-Württemberg, Germany. Email: bettina-johanna.krings@kit.edu [corresponding author].

** Doctor in Sociology, Associate Professor of Industrial Sociology in Faculdade de Ciências e Tecnologia at Universidade Nova de Lisboa, CICS.NOVA - Interdisciplinary Centre of Social Sciences, Lisboa, Portugal. Email: abm@fct.unl.pt

*** Doctoral researcher at the Karlsruher Institut für Technologie. Karlsruhe, Baden-Württemberg, Germany. Email: philipp.frey@partner.kit.edu

RESUMO

Em virtude das possibilidades de inovação colocadas pelas tecnologias digitais, vem crescendo o debate sobre o aumento da automação – não apenas na indústria, mas também em outros ramos e setores das sociedades contemporâneas. Embora os debates público e científico sobre automação pareçam focar questões relevantes do "antigo" debate, como a substituição do trabalho humano pela introdução de novas tecnologias, os autores concentram-se, aqui, no novo aspecto contextual dessas questões. O debate precisa repensar a relação entre tecnologia e trabalho no que concerne às mudanças quantitativas e qualitativas no trabalho. Neste artigo, nosso exemplo será a introdução da automação na indústria, que se refletiu no estudo amplamente reconhecido de Frey e Osborne, de 2013. Eles estimaram impactos profundos da futura informatização sobre os desfechos do mercado de trabalho dos EUA, particularmente em relação ao número de empregos em risco. Surpreendentemente, este estudo foi o ponto de partida para um intenso debate internacional sobre o impacto das tecnologias no futuro do trabalho e o papel da mudança tecnológica nos ambientes de trabalho. Assim, de acordo com os autores, embora as "velhas" questões permaneçam importantes, elas devem ser reinterpretadas considerando as "novas" demandas sociais e expectativas de modelos futuros de trabalho.

Palavras-chave: automação, desemprego técnico, transformação do trabalho, novos modelos de trabalho.

Introduction – Transformation of work by digital technologies

Digital technological applications such as new robotic systems and new forms of artificial intelligence (AI) in the industry are usually considered as the third wave of a technical revolution that is going to fundamentally change highly industrialized societies. According to their proponents, these technologies will not only change the socio-technical environment in "traditional" sectors like agriculture, production, and the service sector. There are future visions that these advanced technological approaches should also be applied in various societal sectors such as medicine, healthcare, or even education (Jasanoff, 2004). Here, robots and AI are not only envisaged to fundamentally change the modes of "productivity", but also the modes of communication, interrelation, and the creation of human-machine interaction (HMI). Some authors even refer to these advances as a "robot society" (van Est & Kools, 2015), a concept that describes the increasing importance of robots in modern working *and* living conditions. What seems interesting here is the major role of technologies as an interdisciplinary approach to complex dimensions of societies. Digital technologies are blurring the boundaries between private and public life, between real and artificial life, but also between work and individual life. Therefore, it has been assumed for decades that digital technologies will completely transform societies and their different functional spheres. In sociology, these technology-based transformation processes are increasingly analyzed and evaluated (Castells, 1996; Huws, 2006; Nassehi, 2019).

Taking into account the impact of these emerging technologies with regard to automation processes, new social, political, and cultural framework conditions seem to continuously change the working environments. This implies significant changes in human-machine interfaces in many branches and sectors which have been observed and debated for two decades. Here, the "old" question whether new technological applications are substituting human labor is guiding these debates (Huws, 2007; Brynjolfsson & McAfee, 2011; 2014; Frey & Osborne, 2013; Arntz, Gregory & Zierahn, 2016; Acemoglu & Restrepo, 2017). At the same time, these debates also focus on future scenarios of (digital) working and living environments. From a global perspective, the quality of human work should become more sustainable as to social and ecological issues (Krings, 2013; Greenfield, 2018). Thus, ethical and social discourses considering these issues seem to be more and more relevant in scientific and public discourses in order to reflect on future models of work.

As sketched above, the current working environments in various sectors are changing, which also has an impact on societal transformation. These changes take place both at the organizational and individual level of working structures and in employment patterns. As the historical view on the mechanization of work shows, various forms of mechanization have never been recognized as endogenous variables by scientific perspectives (Krings, 2011). Conversely, the mechanization of labor has always been considered a "societal-historic development, where economic interests, political power relations as well as cultural values" (Pfeiffer, 2010, p. 231; see also Noon & Blyton, 1997; Ramioul, 2008; Hessler, 2015; Moniz, 2018) should be taken into account. Thus, especially from the perspective of industrial sociology, the effects of technology on labor have always been (critically) analyzed as "saving of labor, increase of effectivity and control of processes" (Pfeiffer, 2010, p. 231). Later, during the 1980s, the issue of qualification – in both senses, upskilling and downskilling processes – has become relevant for analysis, not only in sociology but also in economics and the engineering sciences, regarding the introduction of new technological innovations (Brödner, 2007; Institut der deutschen Wirtschaft, 1976; Pfeiffer, 2016; 2017).

Although the focus on the relationship between technology and work still greatly strengthened work at the operational level, empirical evidence since the 1980s has increasingly shown that there have been many new organizational models of work which cannot be reduced to linear approaches to the relationship between technology and work (Schumann, 2013; Srnicek & Williams, 2015; Moniz, 2018). Furthermore, the increase in service work during the 1970s and 1980s significantly opened up the contingency of work models in industrialized societies and raised questions as to a new quality of labor (Krings, 2007). The widespread application of digital technologies as a key technology and the establishment of the World Wide Web as a new "space of information" (Boes & Pfeiffer, 2006, p. 20; Castells, 1996) enabled "the transformation of work in a global knowledge economy" (Huws, 2006; 2007; Greenan *et al.*, 2009; Greenfield, 2018). This transformation has had and still has tremendous impacts on the restructuring of work at the organizational and individual level, both nationally and internationally, with multiple effects on national and international labor markets (Moniz & Krings, 2016).

This seems to be particularly true for the analysis of digitalization processes and the ongoing introduction of robotics in different fields of work (Moniz, 2014; 2018). However, the impact of these technologies shows that the strong interrelation between technologies and the "traditional" concepts of organizational change can only be partly reconstructed. In addition to the issues mentioned above – saving of labor, increase of effectivity, control of processes, qualification –, technical components in the working structure are increasingly considered as components that provide quantitative and qualitative changes to the whole working structure (Kern & Schumann, 1988; Pfeiffer, 2016). These changes are manifold and differ strongly between sectors and branches (Flecker *et al.*, 2008; EPTA, 2016).

This paper emphasizes the idea of rethinking the relationship between technological development and working environments with regard to new shifts in automation processes in different sectors. It is not a recent debate, but it is gaining new strength through several new empirical studies, new hypotheses based on the economic modeling of the labor market, and new sociological questions. Interestingly, the debate can be reframed with the discussion of the 1970s about automation as a potential cause of deskilling and reducing quality of employment. Later, in the 1980s and 1990s, the discussion focused on the influence of technology on employment volumes and qualification needs (Zuboff, 1988). As a result, technological unemployment and skill shortages became policy issues with a significant resonance in public debate (Noon & Blyton, 1997; Srnicek & Williams, 2015; Mason, 2015). More recently, the application of robotic systems in industrial work introduced new forms of automation that are presented in the social sciences discussion (Van Est & Kools, 2015; Pfeiffer, 2016; Moniz & Krings, 2016; Moniz, 2018). According to the study by Frey and Osborne (2013), these specific forms of automation have led to critical debates about job losses and the changing character of work.

Following sociological theories of work, the focus of our analysis of technological change is not only on the shifts of organizations but also on the shifts of qualifications and skills. In the last decades, many empirical studies based on actual cases and labor market data have provided new perspectives and elements for modeling. However, due to the "second wave-mutation" (Zuboff, 2010) of technological and socio-structural changes, the ubiquitous use of digital technologies offers a wide variety of HMI in all sectors (not only just human-computer interaction HCI). Yet, HMI is rarely empirically examined regarding the shifts of work processes in specific working environments such as the manufacturing industry, administration, care, or even the management of work. The configurations of the future of work must be discussed in more detail, but those configurations often do not reflect issues of labor regulation, issues of transition or even issues of sustainable work models. Moreover, the interrelation between technological progress (production forces) and socio-economic relations (modes of production) is rarely considered when analyzing the application of new information-based technologies.

In the next section, we will investigate the impact of Frey and Osborne's study on scientific and public debates, in order to qualitatively analyze the new forms of automation and employment. We will then discuss new questions arising from these debates with regard to "former" debates on automation processes. Finally, we will reflect on the relationship between technological progress and work and formulate new research questions that should be more strongly embedded in a broad and critical societal debate on future employment models. This kind of critique will be the premise of our reflections on future models of work based on technological progress.

Frey & Osborne – Recent debate on automation

As mentioned by Sonia K. Guimarães (2019, p. 4) on the recent changes in the relation between technological developments and employment structure,

> some analysts predict that the labor market will be divided into two poles – on the high end, knowledge intensive sectors; at the opposite end, activities that can be characterized by low productivity. This scenario also includes a significant reduction of occupations at the middle level and a concomitant growth of societal divisions. Other scholars ponder an increase in the mobility of the labor force, in a globalized scenario in which workers can be recruited from wherever they are found. In this regard, globalization would expand its effects on the labor market".

These new trends are also producing an intense debate in the sociological communities. However, they have their background in economic labor market studies.

The recent debate on automation has been mainly inspired and framed by the seminal and famous study *The future of employment: how susceptible are jobs to computerisation* by Oxford University researchers Carl Benedikt Frey and Michael A. Osborne (2013). They identified the automation of tasks requiring a high level of perceptional skills and dexterity, tasks requiring creative intelligence, and tasks requiring social intelligence as "engineering bottlenecks". Having derived a number of "engineering bottlenecks" from literature review and a workshop with machine learning researchers, they assumed that "[b]eyond these bottlenecks […] it is largely already technologically possible to automate almost any task" (Frey & Osborne, 2013, p. 23). Acemoglu and Restrepo (2019, p. 5) aim towards the same direction when they mention that "advances in robotics, for example, do not make capital or labor more productive, but expand the set of tasks that can be produced by capital". Others, such as Autor, Levy and Murnane (2003, pp.

1280-1281), who were also considered by Frey and Osborne to build their hypothesis, mentioned that their

> model predicts that industries and occupations that are initially intensive in labor input of routine tasks will make relatively larger investments in computer capital as its price declines. These industries and occupations will reduce labor input of routine tasks, for which computer capital substitutes, and increase demand for non-routine task input, which computer capital complements.

This line of argumentation has already demonstrated that computerization affected routine tasks and less skilled jobs in all sectors of the economy by replacing human labor with automated processes. However, at the same time, there is also a need for computerization of non-routine tasks of higher skilled jobs. The two British economists verified that "with falling prices of computing, problem-solving skills are becoming relatively productive, explaining the substantial employment growth in occupations involving cognitive tasks where skilled labour has a comparative advantage, as well as the persistent increase in returns to education" (Frey & Osborne, 2013, p. 3).

Based on data provided by the Occupational Information Network of the Ministry of Employment in the US (O*NET), Frey and Osborne worked on a database of job definitions for hundreds of occupations. Using this database, they carried out an analysis of the share of automatable tasks in more than 700 occupations and came up with the famed result: "according to our estimate, 47 percent of total US employment is in the high risk category, meaning that associated occupations are potentially automatable over some unspecified number of years, perhaps a decade or two" (Frey & Osborne, 2013, p. 38; see Helmrich *et al.*, 2016). The results of the study were noteworthy for a number of reasons:

- The sheer magnitude of the potential for automation that Frey and Osborne identified for almost every second job in the US economy.
- The fact that according to their model and to their own surprise, the brunt of automation might fall upon service occupations that appeared to be growth segments of the labor market in the recent past.
- The move away from largely considering non-routine tasks as not automatable – thanks to progress in the field of machine learning.

At the same time, the scope of their study was much more modest than many commentators led to believe: Frey and Osborne were quick to point out that the subject of their study was merely the susceptibility of jobs in the US economy to automation. However, they also transferred their findings to other national economies that might present a similar challenge due to their differences in job profiles and the composition of labor market structures and institutions. Basically, they came to different results than the study for the United States. Furthermore, they explicitly kept the time horizon relatively open (see above) and had to derive their results from existing literature on digitalization, which might be biased itself.

Most importantly, Frey and Osborne highlighted in their study that one would have to make a number of additional assumptions to derive prognoses of possible net job losses. For instance, regarding the relative costs of automation in the future (influenced by level of wages, labor supply, and the costs of capital equipment), technology will play a quantitative role in the labor market in terms of job substitution and complementarity. In addition, however, we think that there might be regulatory and political resistance to the substitution of jobs, not only by some neo-Luddite movements, but mainly by increasing regulations and safety measures that will provide the framework for the application of automated systems. Lastly, technological development might take longer than predicted and job profiles might adapt to meet the challenge of automation, especially with the complementarity effect. One could add that a massive increase in consumption could easily lead to an expansion of employment despite rising productivity levels, although this might not be ecologically feasible. It is also to be expected that higher qualifications for non-routine tasks in automation environments are not available in abundance in any society and are difficult to find due to inefficiencies of the education and training systems, demographic changes, and profit-oriented organizational cultures.

With regard to the digital transformation of work, the study clearly contributes to triggering intensive national and international debates about the threat of technological unemployment and the future of work. Technical progress and the transformation of work in various sectors in the last decades have been intensively investigated. However, what seemed particularly threatening is that not just manufacturing workers seemed to be at risk of being substituted, but also a large number of white-collar jobs. Thus, according to Frey and Osborne, even jobs in the service sector, such as budget analysts, have a 94% probability of automation (see Frey & Osborne, 2013, p. 69). In view of the enormous number of jobs in the service sector today, this prognosis has raised many existential questions about the future development of societies, since much of these jobs seems to be technologically feasible. Frey and Osborne stated that 47% of jobs in the US featured a probability of more than 70% of being "potentially automatable over some unspecified number of years, perhaps a decade or two" (p. 38).

Other scholars are more cautious when evaluating the societal effect of such results. For example, Arntz *et al.* (2016, p. 25) refer that they

> estimate the automatibility for 21 OECD countries following a task-based rather than an occupation-based approach. For this, we use data on actual workplace tasks as recently surveyed in the PIACC database for OECD countries. Overall, our figures suggest that 9% of OECD jobs are potentially automatable. Moreover, we find that in the US only 9% of jobs rather than 47%, as proposed by Frey and Osborne face a high automatibility. The threat from technological advances thus seems much less pronounced compared to studies following an occupation-based approach.

When applying Frey and Osborne's methodology to Germany, Carsten Brzeski and Inga Burk similarily concluded that 59% of jobs in Germany might be at risk (Brzeski & Burk, 2015). A study by the Leibniz Centre for European Economic Research in Mannheim on behalf of the Federal Ministry of Labour and Social Affairs (BMAS) attempted to apply the methodology of Frey and Osborne to Germany and reduced this figure slightly to 42% (Bonin, Gregory & Zierahn, 2015). Several other studies provide figures in the same range. For example, *A future that works: Automation, employment and productivity* by McKinsey Global Institute concluded that around 45% to 47% of work "activities […] can [!] be automated by adapting currently demonstrated technologies" (Manyika *et al.*, 2017, p. 47) and two studies by the Institute for Employment Research, a special research office of the German Federal Employment Agency, suggested a potential of substitution of around 40%. The same McKinsey methodology was developed for the Portuguese case, and the conclusions were as well very similar (McKinsey, 2019).

In other words, the potential job substitution effect will not be that dramatic since most jobs and occupations consist, by definition, of a combination of routine and non-routine tasks. According to Arntz *et al.*, some traditional occupations in the manufacturing sector, the financial sector (banking, insurance), or other services sectors (legal, accounting) include typical non-routine tasks even though most of their tasks are routinized. Over the last years, many studies have been published in numerous countries on the impacts of technological development on work and employment. The studies revealed significant differences between the institutional framework conditions of employment in these countries, which, in turn, lead to different results. In Germany, for example, new demands for qualification and skills are usually quickly covered by its vocational training system (Fischer, Krings, Moniz & Zimpelmann, 2017) which offers to a great extent the adaptability of human qualification and skills to technical progress. However, it is almost impossible to make a general assessment of the current state of research on automation since the individual studies did not apply the same methodologies, worked with different data, and dealt with a variety of research questions. As to the future of automation, we can distinguish two lines of inquiry: on the one hand, there are studies that explore the *technological potentials* available today or in the near future. On the other hand, there are studies that try to predict actual future *job losses*.

Although these two lines of inquiry can be easily confused, they nonetheless represent a crucial distinction: as discussed above, there are a number of reasons why increased automation cannot simply be equated with aggregate job losses. Reading the simplified statement “every second worker in today’s economy could be substituted by robots and AI” as “we will soon have a rate of 50% technological unemployment” implies that there will be no countervailing job creation at all – an assumption that is highly improbable.

Even if the substitution of human labor were technologically feasible, there is no automatism that would by itself ensure that this automation actually takes place. In fact, the introduction of automation technologies depends on several additional variables, the relative costs of automation playing a central role. If the costs of automation technologies far exceed the amount of wages that can be saved by their introduction, this introduction is likely to be slow throughout the economy. Moreover, a growing political opposition to automation technologies could also slow down their introduction – for instance through legislation, strong union opposition, or worker militancy (Frey & Osborne, 2013, p. 43ff.).

The remarkable merit of the study by Frey and Osborne has again motivated the "classic" question of the interrelation between automation processes and job losses. The overall point of their state of research could then be summarized as follows: scientists agree that there is a great potential for an automation of work, with almost one in two tasks undertaken in today's economy becoming replaceable in the next one or two decades. Furthermore, technology has proven not to undermine total employment in the past and the economic opportunities afforded by technological progress could ensure that employment remains roughly the same while productivity increases. Despite the methodological criticism of the study with regard to its specific design and its comparability with other countries (Pellizzari & Fichen, 2013; EPTA, 2016), its outstanding response in scientific and political communities seems remarkable. It shows that current actual technological progress raises fears, doubts, and hopes about future working conditions in highly industrialized societies.

Technical unemployment? New questions regarding the relationship between technological progress and employment

As sketched above, the study by Frey and Osborne provided an incredible stimulus to the scientific debate on technological unemployment. It gave rise to various economic research strands, with researchers transferring their hypotheses to almost every developed economy in the world and/or developing alternative approaches to the question of automatability (Arntz *et al.*, 2016; Hodgson, 2016; Barbosa *et al.*, 2017). Additional research dealt with the question of how to manage automation "to ensure its benefits are fairly shared" (Lawrence, Roberts & King, 2017). Although these studies deal with societal challenges, there is no clear vision for political action. Questions about future models of work can be asked, but often no policy decisions or options are suggested in this direction. Large global consulting companies such as Boston Consulting, PwC, Deloitte, or McKinsey have been also analyzing the impacts of automatability on the labor market and provided advice to companies and policy makers, however without offering solutions for the replaced job losers.

When Arntz *et al.* revised Frey and Osborne's research and came up with drastically different conclusions, namely that at that time only around 10% of US and UK jobs were under a high risk of automation, many researchers and policy makers had to review their statements and new discussions and data analyses were disseminated. The following quotation shows well that the study has provided many impulses, both at the methodological level and regarding the evaluation of new technologies and their impact on employment:

> the starkly contrasting results were explained by the shift from the occupations-based approach of Frey and Osborne to the task-based approach of Arntz, Gregory and Zierahn. PricewaterhouseCoopers [PwC] examined both studies and developed their own methodology, which not only linked the automatability of tasks that workers must perform, but also the education and training required of the workers themselves in order to do them (Cole, 2019, p. 3).

This means that many more players are now involved in the debate. There are not only economists proposing and testing different models and presenting new concepts, but also consultants, think tanks, and policy advisers who provide input as well.

The well-known MIT economists Acemoglu and Restrepo have been working intensively on this topic over the last years. Their hypotheses, models, and research conclusions contributed to the debate on automation and its impacts on the labor market in regional and national settings. Recently (Acemoglu & Restrepo, 2019, p. 3)), they argued that "some automation technologies may in fact reduce labor demand because they bring displacement effects but modest productivity gains (especially when substituted workers were cheap to begin with and the automated technology is only marginally better than them)". In other words, the automation of mass production (marginal capacity of technology compared to human labor) is the type of technology that can have a major displacement effect (for example, technological unemployment). Another interesting conclusion of their analysis is that "the net impact of automation on labor demand will depend on the broader labor market context. When wages are high and labor scarce, automation will generate a strong productivity effect and will tend to raise labor demand. When wages are low and labor is abundant, automation will bring modest productivity benefits and could end up reducing labor demand" (Acemoglu and Restrepo, 2019, p. 11).

Studies following the other line of inquiry (e.g., Arntz *et al.*, 2018; Brynjolfsson & Mcafee, 2014) tend to highlight the economic opportunities provided by technological development, citing weak positive effects or negligible negative effects on total employment and chances of an upskilling of the work force as well as increased competitiveness supporting strong employment.

In summary, the scientific debate on the automation of work, job displacement, and human-machine interaction leads to the following conclusions (see Acemoglu and Restrepo, 2019, p. 21 ff):

a. Advanced automated systems can be applied to either worsen or improve working conditions.
b. Humans seem to be better at dealing with unexpected events to keep production lines running.
c. The interaction between humans and automated systems increases the importance of safety and responsibility aspects in case of failures or unexpected occurrences.
d. Organizational issues should be strengthened where different options are available.
e. Organizational models capable of achieving flexibility in complex framework conditions are those that combine advanced automated systems with human participation in the decision-making process. Non-participative strategies usually lead to organizational inefficiencies.
f. The creation of new tasks and other technologies raising the labor intensity of production and the labor share are vital for continued wage growth commensurate with productivity growth.

Thrun (2004), Prewett *et al.* (2010), and Heyer (2010) analyzed ergonomic risks and examined safety implications of HMI, so also conceptual contributions from engineering and computer sciences found their way into the debate on automation and human work. At the same time, changes in the manifold dimensions of work increasingly attracted the attention of social scientists. In manufacturing, scientific attention was mainly focused on new qualification and skills requirements, the increase of standardization processes, and polarization processes (Greenan *et al.*, 2009). Only very few studies dealt with the introduction of machines to improve the working conditions by giving the workers more qualified tasks such as programming, maintenance, and control (Anderson & Gartner, 1985; Bernstein, Crowley & Nourbakhsh, 2007; Corbett, Rasmussen & Rauner 1991; Lenz, 2011; Moniz, 2012; Ritter, Sagerer, Dillmann & Buss, 2009).

There is not one single trend in technical development, but a number of them, as pointed out by Krings (2013), Sandberg (1982), and Van Den Besselaar, Clements and Jarvinen (1991), so, it seems difficult to define the relationship between technologies and managerial strategies and its impact on working environments. Empirical studies and data material on these topics are stil scarce. Without doubt, the study by Frey and Osborne was an important starting point to consider the question of technical unemployment again, which also had an impact on sociological research. According to Butera (2015),

> as a result of 50 years of discussions about a changing phenomenon, I define automation as a stage in the process toward integrated systems of processes, technology, organization, roles and values, where technology performs a large variety of existing and new tasks, and where interaction is designed among human beings and technical systems with the goal to get optimal products and services (Butera, 2015, 296).

From that perspective it becomes clear that "automation" is not a mere technological issue, problem, or trend that deserves to be applied to all branches of the economy to aim at higher productivity, higher profits, and a disciplined workforce. On the contrary, it is a socio-technical field in which humans and machines interact in social and societal constellations framed by technology. New forms of HMI have been analyzed in the last decades based on different approaches such as the actor-network theory (Ramioul, 2008; Ritter *et al.*, 2009; Moniz & Krings, 2016) or the role of agency of technologies in different socio-technical environments (Schulz-Schaeffer, 2013). However, these approaches have been mainly developed in the sociology of technology and less in the sociology of work. Thus, there has been a need not only to bridge the gap between both perspectives in recent years, but also a need for interdisciplinary research regarding future models of work (Zubboff, 1988; Krings, 2013; Srnicek & Williams, 2015; Hodgson, 2016; Lawrence *et al.*; Hirsch-Kreinsen & Karacic, 2019).

Nevertheless, the multiple effects of (new) emerging technologies on employment are rather new: new skills and qualification needs emerge, but are not yet available, the volume of employment is threatened by unpredictable changes and capacity building by short-term management policies. Following this debate, the impact of automation seems to be extremely relevant with regard to future models of work. Although automation processes are advancing, there is little conceptual knowledge about the impact of these processes on specific working environments, specific institutional work settings, or labor policies. Thus, it seems that there is still a lack of ideas for the options and chances that these models should provide for sustainable future models of work based on technical progress (Mason, 2015; Krings, 2011; Guimarães, 2019).

Do we need new conceptual approaches of technological progress and work? Some reflections

Innovation processes in the field of digital technologies play a crucial role in analyzing the dynamics of automation in new fields of work such as industry, the service sector, or agriculture (Baukrowitz *et al.*, 2006; Moniz, 2014; 2018). Indeed, the widespread introduction of robotics in the manufacturing industry in recent decades has been quantitatively remarkable in many countries. However, these developments have not been scientifically analyzed as to the transformation of work. Based on the debate on digital technologies in different fields of work, today, most production models that envisage higher productivity levels belong to the field of artificial intelligence and machine learning applied to manufacturing tasks.

But there are also the social aspects of automation that are not yet solved. Some of those aspects are related to ergonomic design, but most of them deal with responsibility, situation awareness, risk assessment, and the quality of working life. In safer cooperative working conditions, there are relevant topics that we can call "social implications of robotics". Nevertheless, the strong interrelation between technologies *and* organizational change can only be partially reconstructed. The impact of these innovations on structure of work as well as on employment still is not well known.

In addition to the issues mentioned above – labor saving, increased effectivity, process control, qualification – technical components and technical systems in the work structure are more and more considered as components that bring about quantitative and qualitative changes in complex automation processes (Kern & Schumann, 1988; Pfeiffer, 2010; 2017). These changes are manifold and differ strongly between sectors and branches (Flecker *et al.*, 2008). Whereas organizational changes and changes in value chains are widely analyzed by empirical studies, the variety of consequences of automation still seems to be largely unknown. In the last years, the impact on the societal level has become an important topic of public and political discourses regarding the dynamics of automation and its effects on the (un)employment structure. However, this impact has hardly been analyzed and assessed. This seems especially true in relation to the "limits to growth" (Meadows, Meadows, Randers & Behrens, 1972) and sustainable work models.

Currently, the occurrence of different technological innovations is transforming almost every field of work with regard to different issues, especially automation. Even in social fields of work that were traditionally considered "non-technical" (e.g., health care or education) work routines can be automated by new technologies. This can also be observed in technology-based fields where new technological innovations are continuously introduced and continuously change work routines and activities.

The use of surgical robots is one example. However, failures of this technology in its historic development even seemed to be the incentive to improve it instead of investigating its impact on the working environment (Caetano da Rosa, 2013). This example reflects a growing number of complex technical systems that underpin the transformation of professional practices, which – ultimately – influences the whole socio-technical field (Drews, 2011; Moniz & Krings, 2016). The social dimension derived from the possibilities of worker-robot interaction in the industry also becomes a crucial aspect of this framework, where efficiency and control are now, as explained above, elements of the working process.

At the same time, new organizational models create new forms of social division of labor, new (technology-based) professions, and – usually – new organizational options for medical devices. However, the medical sector, unlike the industrial production sector, cannot use the progress of technical innovation for the automation of work to a large extent. Here, empirical research shows that new socio-technical work situations arise, which integrate technology into medical work. Thus, the example shows a technical potential for transformation in a broad range of medical work routines (Caetano da Rosa, 2013, p. 147ff.). Nevertheless, the automation process may take place in related fields of medical work, since these dynamics usually lead to "standardization, laws, and reimbursement rules" (Caetano da Rosa, 2013, p. 148), what means important issues of workplace transformation on a long temporal scale. The impact of these changes is remarkable in view of the decreasing quality of medical work (Wehling, Viehöfer & Koenen, 2015), which raises the question of the benefits of these transformations. This can also happen in other sectors where non-routine tasks in highly skilled jobs are still not automated, but digitalization processes have already been introduced.

Regardless of the sector and the industry, the question remains on how automation can be managed to develop future models of work. This also seems to be a relevant question for social scientists and not only for engineers or managers.

Building on the fruitful debates sparked by Frey and Osborne, interdisciplinary knowledge about HMI is required, based on approaches from science, technology, and society studies (STS), case study research, workplace observation etc. Furthermore, we argue that the inclusion of employees' needs at the level of technology design is also required to bridge the gap between work and technologies. Different technical options should be fully analyzed and assessed once the social impact within organizations might be very important. Without such a debate on technological options, labor movements as well as labor unions will be limited to accompany and to accept socio-technical transformation by the established organizational settings. The participative strategies should include different learning processes, competence building, and decentralized decision making to provide ways to reduce the potential for job replacement with automated systems. In such disruptive environments (labor market changes, skills shortages, technology development), efficiency can be derived from participatory organizations rather than from traditionally managed systems that would intensify the trends of precarization and deskilling of human work.

Such conclusions also mean that the design of HRI should be "human-centered", which means participative and integrative regarding the needs of the workers. Technocratic visions still understand such a human place in technical systems as instrumental to organizational efficiency, but real humanistic (or anthropocentric) visions would understand it as important steps toward an improvement of the working life. These are principles that are most relevant in production environments and that have been neglected in the last two decades. The development of work skills, distributed decision making, and task enrichment systems should integrate new technological developments to improve the quality of work standards in automated environments.

Particularly challenging in this debate is that the service sectors that formerly compensated for job losses in the manufacturing industry are now also subject to automation processes. Moreover, the erosion of the welfare state in many industrialized countries might weaken the potential for adequate policy responses to the challenges of automation. It seems that both the modern concept of "labor" and the modern concept of "technology" must be questioned here. Obviously, this cannot be done in our article, but it is our intention to raise awareness of the impacts of technologies in working environments on a larger scale. These impacts are manifold and vary within industries and professions. A lot of social research is necessary to create knowledge about transformation processes at micro, mezzo and macro levels. However, technologies always do reflect economic interests, political power relations, and cultural values in changing socio-technical environments (Jasanoff, 2004). This is particularly the case when the normative power of technologies is also used as a metaphor for economic efficiency and economic growth in work processes. From this perspective, reflecting on technologies always implies reflecting on the quality of work as well as the question of how and with what expectations human work will be organized in future societies.

References

Acemoglu, Daron & Restrepo, Pascual. (2017). *Robots and jobs: evidence from US labor markets*. Working Paper, no. 23285. NBER – National Bureau of Economic Research. doi:10.3386/w23285

Acemoglu, Daron & Restrepo, Pascual. (2019). *Automation and new tasks: how technology displaces and reinstates labor*. Discussion Paper Series, no. 12293. IZA ´Institute of Labor Economics.

Anderson, Roger L.; Gartner, William B. (1985). When robots and people work together, *Robotics, 1*(2), 69-76.

Arntz, Melanie, Gregory, Terry. & Zierahn, Ulrich. (2016). *The risk of automation for jobs in OECD countries: a comparative analysis*. OECD Social, Employment and Migration Working Papers, no. 189, OECD Publishing, Paris. http://dx.doi.or g/10.1787/5jlz9h56dvq7-en

Autor, David H., Levy, Frank & Murnane, Richard J. (2003). The skill content of recent technological change: an empirical exploration. *The Quarterly Journal of Economics, 118*(4), 1279-1333

Barbosa, Carlos E. *et al.* (2017). *Working in 2050: a view of how changes on the work will affect society.* Rio de Janeiro: Laboratório do Futuro – UFRJ.

Baukrowitz, Andrea; Berker, Thomas; Boes, Andreas; Pfeiffer, Sabine; Schmiede, Rudi; Will, Mascha (Ed.)(2006): Informatisierung der Arbeit – Gesellschaft im Umbruch. Berlin: edition sigma

Bernstein, Debra, Crowley, Kevin & Nourbakhsh, Illah R. (2007). Working with a robot: Exploring relationship potential in human-robot systems. *Interaction Studies, 8*(3), 465-482.

Boes, Andreas; Pfeiffer, Sabine (2006). *Informatisierung der Arbeit – Gesellschaft im Umbruch*. Eine Einführung. In Andrea Baukrowitz *et al.* (eds.) Informatisierung der Arbeit – Gesellschaft im Umbruch. (pp. 19-34) Berlin: Sigma.

Bonin, Holger, Gregory, Terry & Zierahn, Ulrich. (2015). *Übertragung der Studie von Frey und Osborne (2013) auf Deutschland*. Kurzexpertise no. 57, Mannheim, ZEW. http://ftp.zew.de/pub/zew-docs/gutachten/Kurzexpertise_BMAS_ZEW2015.pdf

Brödner, Peter. (2007). From Taylorism to competence-based production. AI & Society, 21(4), 497-514.

Brynjolfsson, Erik & McAfee, Andrew. (2011). *The race against the machine: how the digital revolution is accelerating innovation, driving productivity and irreversibly transforming employment and the economy*. Lexington, KY: Digital Frontier Press.

Brynjolfsson, Erik & McAfee, Andrew. (2014). *The second machine age: work, progress, and prosperity in a time of brilliant technologies*. New York: W. W. Norton & Company.

Brzeski, Carsten & Burk, Inga. (2015). *Die Roboter kommen: Folgen der Automatisierung für den deutschen Arbeitsmarkt*. Economic Research. Frankfurt am Main: ING-DiBa https://www.ing-diba.de/pdf/ueber-uns/presse/publikationen/ing-diba-economic-analysis-die-roboter-kommen.pdf

Butera, Frederico. (2015). Automation: organizational studies. In *International Encyclopedia of the Social and Behavioral Sciences*. 2nd edition, v. 2. Elsevier.

Caetano Da Rosa, Catarina. (2013). *Operationsroboter in Aktion. Kontroverse Innovationen in der Medizintechnik*. Bielefeld: transcript-Verlag.

Castells, Manuel. (1996). *The rise of the network society. The Information Age: Economy, Society and Culture*, v. I. Cambridge, MA and Oxford, UK: Blackwell.

Cole, Matt. (2019). *Automation*. Autonomy.work. https://autonomy.work/wp-content/uploads/2018/08/Automation-V6.pdf

Corbett, J. Martin, Rasmussen, Lauge B. & Rauner, Felix. (1991). *Crossing the border. The social and engineering design of computer integrated manufacturing systems*. London/Berlin: Springer.

Drews, Paul (2011). Telemedicine – ICT based transformation of knowledge-intensive work in health care. *In:* Bettina-Johanna Krings (ed.) *Brain drain or brain gain? Changes of work in knowledge-based societies* (pp. 129-150). Berlin: Edition Sigma: Berlin.

EPTA - European Parliamentary Technology Assessment. (2016). *The Future of Labour in the Digital Era: Ubiquitous Computing, Virtual Platforms, and Real-time Production*. Vienna: EPTA. epub.oeaw.ac.at/ita/ita-projektberichte/EPTA-2016-Digital-Labour.pdf

Fischer, Martin; Krings, Bettina-Johanna, Moniz, António B. & Zimpelmann, Eike. (2017) Herausforderungen der Mensch-Roboter-Kollaboration. *Lernen & Lehren, 32* (125), 8–14.

Flecker, Jörg, Holtgrewe, Ursula, Schönauer, Annika, Dunkel, Wolfgang & Meil, Pamela. (2008): *Restructuring across value chains and changes in work and employment. Case study evidence from the Clothing, Food, IT and Public Sector*. WP 10 Organisational Case Studies – Synthesis Report. WORKS-Work organisation and restructuring in the knowledge society.

Frey, Carl B. & Osborne, Michael A. (2013): *The future of employment: how susceptible are jobs to computerisation?* Oxford: The Oxford Martin School.

Greenan, Nathalie, Kocoglu, Yusuf, Walkowiak, Emmanuelle, Csizmadia, Péter & Makó, Csaba. (2009). *The role of technology in value chain restructuring*. WORKS-Work organisation and restructuring in the knowledge society.

Greenfield, Adam. (2018). *Radical technologies: the design of everyday life*. London: Verson.

Guimarães, Sonia K. (2019). Dossier: Sociological perspectives on the new digital technologies, *Sociologies in Dialogue, 5*(1), 2-9. doi: 10.20336/sid.v5i1.109

Helmrich, Robert *et al.* (2016). *Digitalisierung der Arbeitslandschaften. Keine Polarisierung der Arbeitswelt, aber beschleunigter Strukturwandel und Arbeitsplatzwechsel*. Bundesinstitut für Berufsbildung, Wissenschaftliche Diskussionspapiere, no. 180. https://www.bibb.de/veroeffentlichungen/de/publication/download/8169

Heyer, Clint. (2010). Human-robot interaction and future industrial robotics applications. *In: 2010 IEEE/RSJ: Proceedings of the International Conference on Intelligent Robots and Systems*. (pp. 4749-4754). Taipei, IEEE.

Hessler, Martina. (2015). Die Ersetzung des Menschen? Die Debatte des Mensch-Maschinen-Verhältnisses im Automatisierungsdiskurs. *Technikgeschichte, 82*(2), 110-136.

Hirsch-Kreinsen, Hartmut & Karačić, Anemari (orgs.). (2019). *Logistikarbeit in der digitalen Wertschöpfung – Perspektiven und Herausforderungenfür Arbeit durch technologische Erneuerungen*. Tagungsdokumentation. Düsseldorf: FGW

Hodgson, Geoffrey M. (2016). The future of work in the twenty-first century. *Journal of Economic Issues, 50*(1), 197–216.

Huws, Ursula (ed.). (2006). *The transformation of work in a global knowledge economy: towards a conceptual framework*. Workpackage 3: Theories and concepts. WORKS-Work organisation and restructuring in the knowledge society.

Huws, Ursula. (2007). Defragmenting: towards a critical understanding of the new global division of labour. *Work organization, Labour & Globalization, 1*(2), 1-4.

Institut der deutschen Wirtschaft. (org.) (1976). Die Humanisierung – Industriearbeit im Wandel. Köln.

Jasanoff, Sheila (ed.). (2004). *States of knowledge: the co-production of science and social order*. London: Routledge.

Kern, Horst & Schumann, Michael. (1988). *El fin de la división del trabajo. Racionalización en la producción industrial*. Madrid: Ministerio de Trabajo y Seguridad Social.

Krings, Bettina-Johanna. (2007). Die Krise der Arbeitsgesellschaft. Einführung in den Schwerpunkt. *Technikfolgenabschätzung Theorie und Praxis (TATuP), 16*(2), 4-12.

Krings, Bettina-Johanna (ed.). (2011) *Brain drain or brain gain? Changes of work in knowledge-based societies*. Edition Sigma: Berlin

Krings, Bettina-Johanna. (2013). Arbeit und Technik. In Armin Grunwald (ed.). *Handbuch Technikethik* (pp.217-222). Stuttgart: J.B. Metzler.

Lawrence, Mathew, Roberts, Carys & King, Loren. (2017). *Managing automation. Employment, inequality and ethics in the digital age*. Discussion Paper. IPPR Commission on Economic Justice. http://www.ippr.org/publications/managing-automation

Lenz, Claus. (2011). *Context-aware human-robot collaboration as a basis for future cognitive factories*. PhD thesis, Munich: Technische Universität München.

Manyika, James *et al.* (2017). *A future that works: automation, employment, and productivity*. S. Francisco: McKinsey & Co.

Mason, Paul. (2015). *PostCapitalism: a guide to our future*. London: Penguin.

McKinsey & Company. (2019). *Automação e futuro do emprego em Portugal*. Lisbon: McKinsey & Company.

Meadows, Donella H., Meadows, Dennis L., Randers, Jørgen & Behrens, William W. (1972). *The limits to growth*. New York: Universe Books.

Moniz, António B. (2012). Anthropocentric-based robotic and autonomous systems: assessment for new organisational options. In Michael Decker and Mathias Gutmann (eds.). *Robo- and Informationethics: some fundamentals*. (pp. 123-157). Zurich: LIT.

Moniz, António B. (2014): Organisational challenges of human-robot interaction systems in industry: human resources implications, *In:* Machado, C.; Davim, J.P. (Hrsg.): Human Resource Management and Technological Challenges. Cham Heidelberg New York u.a.: Springer, p. 123-131.

Moniz, António B. (2018). *Robótica e trabalho: o futuro hoje*. Lisbon: Glaciar/ FLAD.

Moniz, António B. & Krings, Bettina-Johanna. (2016). Robots working with humans or humans working with robots? Searching for social dimensions in new human-robot interaction in industry. *Societies, 6*(3), 23.

Nassehi, Armin. (2019). *Muster. Theorien der digitalen Gesellschaft*. München: C. H. Beck Verlag.

Noon, Mike & Blyton, Paul. (1997). *The realities of work – experiencing work and employment in contemporary society*. London: Macmillan.

Pellizzari, Michele & Fichen, Anne (2013). *A new measure of skills mismatch: theory and evidence from the survey of adult skills (PIAAC)*. OECD Social, Employment and Migration Working Papers, no. 153. Paris: OECD Publishing. doi: 10.1787/5k3tpt04lcnt-en

Pfeiffer, Sabine. (2010). Technisierung von Arbeit. In Fritz Böhle, G. Günter Voß & Günter Wachtler (eds.). *Handbuch Arbeitssoziologie*. (p. 231-262) Wiesbaden: VS-Verlag.

Pfeiffer, Sabine. (2016). Robots, Industry 4.0 and humans, or Why assembly work is more than routine work. *Societies, 6*(2), 16.

Pfeiffer, Sabine. (2017). The vision of 'Industrie 4.0' in the making - Case of future told, tamed, and traded. *Nanoethics, 11*(1), 107–121, doi: 10.1007/s11569-016-0280-3

Prewett, Matthew. S. *et al.* (2010). Managing workload in human-robot interaction: A review of empirical studies. *Computers in Human Behavior, 26*(5), 840-856.

Ramioul, Monique. (2008). Work organisation and restructuring in the knowledge society. *Enterprise and Work Innovation Studies, 4*(4), 9-19.

Ritter, Helge, Sagerer, Gerhard, Dillmann, Rüdiger & Buss, Martin (eds.). (2009). *Human centered robot systems. Cognition, interaction, technology*. Berlin: Springer.

Sandberg, Thomas. (1982). *Work organization and autonomous groups*. Lund: LiberFörlag.

Schulz-Schaeffer, Ingo. (2013). Scenarios as patterns of orientation in technology development and technology assessment. Outline of a research program. *Science, Technology & Innovation Studies 9*(1), p. 23-44.

Schumann, Michael. (2013). *Das Jahrhundert der Industriearbeit. Soziologische Erkenntnisse und Ausblicke*. Weinheim, Basel: Beltz Verlag.

Srnicek, Nick & Williams, Alex. (2015). *Inventing the future. Postcapitalism and a world without work*. London: Verso Books.

Thrun, Sebastian. (2004). Toward a framework for human-robot interaction. *Human-Computer Interaction, 19* (1-2), 9-24.

Van Den Besselaar, Peter, Clements, Andrew & Jarvinen, Pertti (eds.). (1991). *Information system, work and organization design*. Amsterdam: North-Holland/IFIP.

Van Est, Rinie & Kools, Linda (eds.). (2015). *Working on the robot society*. The Hague: Rathenau Instituut.

Wehling, Peter, Viehöfer, Willy & Koenen, Sophia (eds.) (2015): *The public shaping of medical research*. Patient associations, health movements and biomedicine. London, New York: Routledge.

Zuboff, Shoshana. (1988). *In the age of the smart machine: the future of work and power*. New York: Basic Books: New York.

Zuboff, Shoshana. (2010). Creating value in the age of distributed capitalism. *McKinsey Quarterly, 4*, 45–55.

Submitted on April 29, 2020.
Approved on August 10, 2020.