Humans versus Machines: An Overview of Research on the Effects of Automation of Work

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Executive summary[1]

In the scholarly discussions, automation is commonly used as an umbrella concept to include various advanced technologies, such as computers, advanced robotics and artificial intelligence. Research evidence from labour economics suggests that, while the number of middle-skilled jobs are decreasing due to task automation, new jobs are being created for nonroutine tasks, both for high and low-level skilled workers.

This paper analyses our current state of knowledge and identifies the gaps in the literature, with a special focus on Germany. It emphasises the shortcomings in the literature, regarding the instruments that help the transition of workers to new occupations, the effects of automation on vulnerable workers, the role and the effects of automation on vocational training and the role of workers' voice.

What is digital automation?

The automation of work is generally understood as the replacement of human labour input with that of machines or, in other words, with capital (Eurofound, 2017, Acemoglu and Restrepo, 2019). This is not a new development, for machines have been replacing human labour throughout the past two centuries. What distinguishes automation today from previous periods is its use of digital technologies, which was made possible with the invention of the microprocessor during the early 1970s. Thanks to the microprocessor, the digital revolution has unravelled at an increasing pace, with reliable network connections, big data analytics, algorithmic decision-making and digital sensors at its core.

Machines, tasks and jobs: The routine biased technological change approach

How many jobs have been taken over by machines so far? Which jobs and occupations have the highest risk of being automated? Will human labour be irrelevant in the future world of work? These questions have recently caught widespread scholarly attention. Many researchers scrutinise these issues by utilising an approach commonly known as 'routine biased technological change' (hereafter, RBTC).

[1] This executive summary presents main findings of our working paper: Humans versus Machines: An Overview of Research on the Effects of Automation of Work, available at: https://digitalage.berlin/wp-content/uploads/2021/02/Ozkiziltan_Hassel_Automation_18-08-20.pdf.The research is conducted as a part of 'Governing Work in the Digital Age' project based at the Hertie School of Governance, Berlin. It is funded by German Federal Ministry of Labour and Social Affairs (BMAS).

The RBTC hypothesis holds several key assumptions (Autor *et al.*, 2003, Arntz *et al.*, 2016b, Eurofound, 2016, Nedelkoska and Quintini, 2018). Some of these are:

- Tasks and skills are two different variables. A task is a unit of activity performed at work and it produces output. Skills are human capabilities required to fulfil a task. At least currently, automation replaces tasks rather than skills. Any task can be performed by machines as well as by workers, depending on technological advancements and the cost of automation relative to human labour.
- Automation mostly replaces routine tasks, which follow a well-defined practise. Routine tasks can be performed manually or cognitively and are often included in middle-paid, middle-skilled jobs, such as in bookkeeping, clerical work and production.
- Automation complements manual and cognitive nonroutine tasks related to problem-solving and complex communication activities. Manual nonroutine tasks are difficult for machines to replace because these require adaptability, visual and language skills as well as personal interactions. These jobs are prevalent in low-paid service occupations, such as catering, cleaning, janitorial work, health, childcare, care of the elderly and security services. Cognitive nonroutine tasks involve problem-solving, intuition, creativity, and persuasion. Typically, professional, technical and managerial occupations, such as medicine, engineering, design, science, law and marketing, fall into this category.

Human vs. machine: Employment in times of automation

So far, two main arguments have dominated the debate on the replacement of human labour by machines in the RBTC literature.

Argument 1: Machines are increasingly able to master manual and cognitive tasks performed at work, which would render humans obsolete in future labour markets (Frey and Osborne, 2013, Bowles, 2014, Brzeski and Burk, 2015, Brynjolffson and McAfee, 2016).

This argument is spearheaded by Frey and Osborne (2013) (hereafter, FO) with the claim that the automation of almost any task and occupation is technologically achievable if adequate data are collected for pattern recognition. According to FO, 47 % of total US employment faces a high risk of disappearing by 2033. By applying FO's methodology, Bowles (2014)

estimated that between 45 and 60 % of jobs in Europe are at a high risk of disappearing within the next 20 years. With the same methodology, Brzeski and Burk (2015) found that 59 % of jobs are at a high risk of being replaced by automation in Germany by 2033.

According to some authors, FO's study suffers from two important drawbacks: First, the task content information of the O*NET dataset utilised in their study rests on the assessment of researchers and experts of the labour market and workers in a particular occupation. Thus, the O*NET dataset is incapable of providing the individual task composition of each job/occupation across the labour market (Arntz *et al.*, 2016a, Nedelkoska and Quintini, 2018). Second, critics point out that occupations consist of various tasks bundled with each other, and it is the tasks, rather than entire occupations, that are susceptible to automation (Arntz *et al.*, 2016a, Eurofound, 2018).

Addressing these gaps, Arntz *et al.* (2016a) re-estimated the proportion of jobs that are at risk from automation for 21 OECD countries, including the US. In their analysis, the authors have used OECD's 2012 PIACC database (Programme for the International Assessment of Adult Competencies), that is based on individual survey data and provides a comprehensive list of tasks workers actually carry out at their workplace. Arntz *et al.* (2016a) observed that, on average, 9 % of jobs are highly automatable across the 21 OECD countries, although they have found discrepancies across OECD countries, with the share of highly automatable jobs being 6 % in Korea, 12 % in Germany and 9 % in the US.

Nedelkoska and Quintini (2018) also analysed the risk of job losses through automation by building on the work done by Arntz *et al.* (2016a) and utilising the OECD's PIACC database for the years 2011/2012 and 2014/2015. The authors calculated that around 14% of jobs in OECD countries are highly automatable, affecting over 66 million workers in the 32 countries covered by the study. Nedelkoska and Quintini (2018) ascertained that the actual risk of automation varies significantly across countries, from 33% of all jobs in Slovakia, to 18% in Germany and 6% in Norway.

Argument 2: Automation leads to employment polarisation in the job markets of advanced economies (Autor *et al.*, 2003, Spitz-Oener, 2006, Goos *et al.*, 2014, Eurofound, 2016, Bisello *et al.*, 2019).

Employment polarisation addresses a hollowing-out process in job markets, where a decrease in the share of routine-intensive, middle-paid, middle-skilled jobs is accompanied by growing shares of nonroutine-intensive, highly paid, highly skilled jobs as well as nonroutine-

intensive, low-paid, low-skilled jobs. Pioneered by Autor *et al.* (2003), the proponents of the employment polarisation argument have come up with comparably similar and complementary results for different country cases. Autor *et al.* (2003) found that digital automation reduced the use of routine manual and routine cognitive tasks, while increasing the use of nonroutine cognitive tasks within industries, occupations, and education groups in the US from 1960 to 1998. Goos *et al*. (2014), Eurofound (2016) and Bisello *et al.* (2019) all ascertained that, during the last few decades, routine tasks, which are repetitive and/or require physical strength, were decreasing, while nonroutine tasks, relating to social, literary and ICT (information and communications technology) skills, were on the increase across European countries.

Applied to Germany, the employment polarisation argument has returned some interesting findings. For example, Spitz-Oener (2006) unearthed a considerable decline in cognitive and manual routine tasks, which used to be performed by middle-skilled labour, and a noticeable increase in analytical and interactive activities, that require highly educated, highly skilled workers, in the 1979-1999 period. A body of recent research also confirmed a remarkable and continuous change in employment, away from routine, middle-skilled occupations and towards an increased automation of work in Germany (Fernández-Macías, 2015, Consoli and Roy, 2017, Bachmann *et al.*, 2019).

Some recent studies brought regional and individual effects of employment polarisation in Germany into the open. Regarding the former, Consoli and Roy (2017) ascertained that the increase in imports in goods and services contributed to the decline in the number of routine jobs in West Germany. They also observed that, in the regional employment districts of West Germany, where the share of routine occupations was initially high, a higher adoption of ICT and a larger decline in the share of routine jobs occurred between the years 1979-2012.

When it comes to the impact of automation on individuals in Germany, Bachmann *et al.* (2019), discovered that those working in routine jobs face a higher risk of unemployment in both one year (short term) and five years (medium term) of employment. However, the authors also revealed that the disadvantage of being in a routine job is partly offset by a higher rate of being able to find other jobs. Another individual-level study was conducted by Janssen and Mohrenweiser (2018), with the observation that, during periods of fast technological transformation in the German metalworking industry, the incumbents with outdated skills are more likely to lose their jobs to newly graduated entrants with up-to-date

IT skills. Despite this, they do not experience much unemployment, as they change their occupations within that industry or switch to service sector jobs.

Humans competing with machines: The dynamics explained

The available evidence suggests that automation has so far created more new jobs than it has destroyed, rendering humans able to compete with machines rather than against them (Arntz *et al.*, 2016b, Goos *et al.*, 2019). Why does RBTC not negatively affect aggregate employment levels across developed economies, despite it replacing routine tasks? In explaining this puzzle, Acemoglu and Restrepo (2019) point out three adjusting mechanisms: First is automation's *displacement effect,* addressing the direct replacement of human labour by machines. Second is the *productivity effect*, denoting a growing labour demand for non-automated tasks (i.e. childcare, personal care, catering, sales) thanks to the decreasing price of automated tasks boosting the economy. Third is the *reinstatement effect*, indicating the creation of new tasks, in which labour has a comparative advantage (i.e. designing, operating and maintaining new machines and software).

Some other forces also operate simultaneously with these three adjusting mechanisms of automation: First, **various economic, social and political issues** create obstacles for the everyday use of new technologies. In the economic realm, despite the theoretical possibility that all tasks can be automated, in real life tasks are automated when doing so would generate more profit (Acemoglu and Restrepo, 2018). What is more, the adoption of new technologies requires organisational restructuring, new skills, and new employees, all of which incur extra costs for companies (Brynjolfsson *et al.*, 2019). Regarding social and political issues, minimum wage mechanisms, collective bargaining, and other wage-setting institutions play an important role in a company's decision to automate tasks, for this might exert a noticeable impact on labour costs (Arntz *et al.*, 2019). Furthermore, the utilisation of some new technologies, as in the case of driverless cars, requires the consideration of various ethical and legal dilemmas that have yet to be resolved (Bonnefon *et al.*, 2016, Lee, 2017). It is also pointed out that, even if some tasks are fully automatable, for instance, music production or artisan baking, people might prefer human labour over machines in the performance of some tasks (Pratt, 2015), rendering humans capable of competing with, rather than against, machines.

Second, as was indicated by MIT (2019), many developed economies are currently experiencing a remarkable **demographic transformation,** triggered by factors such as

sluggish rates of labour force growth, plummeting ratios of workers to retirees and stricter immigration policies. Thus, according to MIT (2019: 10), "over the next two decades industrialized countries will be grappling with more job openings than able-bodied adults to fill them."

Third, it is argued that an introduction of new technologies to the workplace tends to change the **task composition** of jobs rather than replacing entire occupations (Spitz-Oener, 2006, Arntz *et al.*, 2016b, Arntz *et al.*, 2019). This alteration in task composition causes those working in occupations with a high risk of automation to undertake tasks that are difficult to automate (Arntz *et al.*, 2017, Arntz *et al.*, 2019). Indeed, according to Dauth *et al.* (2021), in the 1994-2019 period, robot-exposed workers in Germany were more likely to keep their existing jobs with a possible change in its task composition. Similarly, Spitz-Oener (2006) found that, in the period covering the years 1979-1999, more than 99 % of workers in West Germany adjusted their tasks in accordance with changing technology, and fewer than 1 % of workers lost their jobs directly as a result of their labour being replaced by machines.

Automation: The restructuring of work

In the automation literature, it is commonly argued that technological developments upgrade the skill requirements for occupations (Brynjolffson and McAfee, 2016, Eurofound, 2017, Goos *et al.*, 2019). These upgraded skills are made up of a novel combination of hard and soft skills. Hard skills are comprised of those related to ICT, such as a command of various operating systems and office software, basic coding, and graphic design. Soft skills are the cognitive nonroutine ones, including interpersonal interaction, social intelligence, entrepreneurial thinking, creativity, flexibility, adaptability, and problem solving (Eurofound, 2017). Research evidence also indicates that new technologies increasingly facilitate different work arrangements, such as job offshoring, outsourcing, use of home offices, platforms and crowdsourcing (Goos *et al.*, 2014, Eurofound and ILO, 2017). These changes in skill requirements and work arrangements, in turn, are considered to bear some serious consequences on the structure of work and employment.

First, as the skill requirements of jobs change, middle and low-skilled, middle and low-educated workers come out as the losers of automation. This is because they are placed under a lot of pressure to embrace the changing nature of work by taking occupational training to gain new skills and/or upgrade the ones they have. Yet research evidence shows that these are

the ones who have difficulties in accessing these upgrading opportunities (Bassanini and Ok, 2004, Albert *et al.*, 2010).

Second, automation, by creating a large group of losers, feeds into the already exacerbated inequalities in the world of work. If workers cannot adjust to changes, either their wages fall into a relative decline compared to highly skilled workers (Cortes, 2016, Dauth *et al.*, 2021) or they are forced to accept lower-skilled, lower-paying jobs (Autor and Dorn, 2013, Janssen and Mohrenweiser, 2018). For instance, in the case of Germany, as was observed by Janssen and Mohrenweiser (2018), following the introduction of CNC (Computerized Numerical Control) in the metalworking industry, incumbent workers with outdated skills experienced lower wage growth, became less likely to receive a promotion at work and more likely to switch their occupation, and had to increasingly accept low-wage service jobs.

Third, this rising inequality in the world of work is likely to affect women, younger (OECD, 2019) and older (Aubert *et al.*, 2006, Autor and Dorn, 2009) workers as well as those without tertiary degrees (OECD, 2019), as these are the ones who often find themselves in the position of having to opt for the jobs located on the lower end of the job spectrum.

Fourth, even for workers with little risk of losing their jobs, the new world of work poses various challenges. For instance, as the physical boundaries are increasingly disappearing with the use of new technologies, many workers find themselves working in isolation, with little or no prospect of collective representation and solidarity (Eurofound, 2018, Parolin, 2019). What is more, in highly skilled jobs, such as managerial and professional occupations, a significant increase in repetitiveness and standardisation has been reported, suggesting that automation facilitates the routinisation of some previously nonroutine cognitive tasks (Bisello *et al.*, 2019).

Fifth, it is reported that those coworking with robots find themselves in a work environment where they constantly need to acquire new qualifications, and technical and organisational capabilities. This constant need for change occurs mostly because system integrators and robot manufacturers rarely consider the social impact of new technologies on working environments (Moniz and Krings, 2016).

The gaps in the employment polarisation literature

The employment polarisation literature embodies a growing body of empirical studies. However, there are still under-researched areas, such as:

- How are German vocational training schemes affected by employment polarisation and how can mid-level skills be protected?
- How are different groups in the labour market affected by automation, in particular vulnerable groups, such as women, younger, disabled, older and migrant workers, and workers of different ethnic origins? Can transition instruments help to avoid segregation in the labour market and foster social cohesion?
- How do these different groups of workers utilise vocational training and life-long learning opportunities? Are there differences in different groups of workers as to how they receive and make use of their training prospects?
- How does automation affect workers' voice and vice versa? Are workers from different sectors, of differing skill levels and different socioeconomic backgrounds (e.g., women, older and younger workers, migrant workers) exercising their agency in different ways to contribute to better working conditions?
- How can vocational training cope with employment polarisation?

Conclusion

Currently, there is a growing body of literature highlighting the ways digital automation is transforming the world of work by changing the division of labour between humans and machines. As Germany relies heavily on mid-level skills and invests heavily in apprenticeships, future studies need to carefully examine the ways in which German training institutions can provide upward mobility for middle-skilled, middle-educated workers. Furthermore, given the fact that the influence of works councils and trade unions in the German system is still pervasive (though declining), we should expect that co-decision rights and collective agreements shape the trajectory of technology-driven corporate restructuring. Studies in labour economics have, however, rarely associated the role of workers' voice with automation. To overcome this research gap, it is recommended that further research be undertaken to apply the insights from industrial sociology to the existing data and findings on employment polarisation. Finally, research on the effects of automation rarely considers the individual characteristics of workers. A new research agenda should pay special attention to vulnerable and marginalised groups in the labour markets and embody the best practices of workers coping with labour market restructuring.

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