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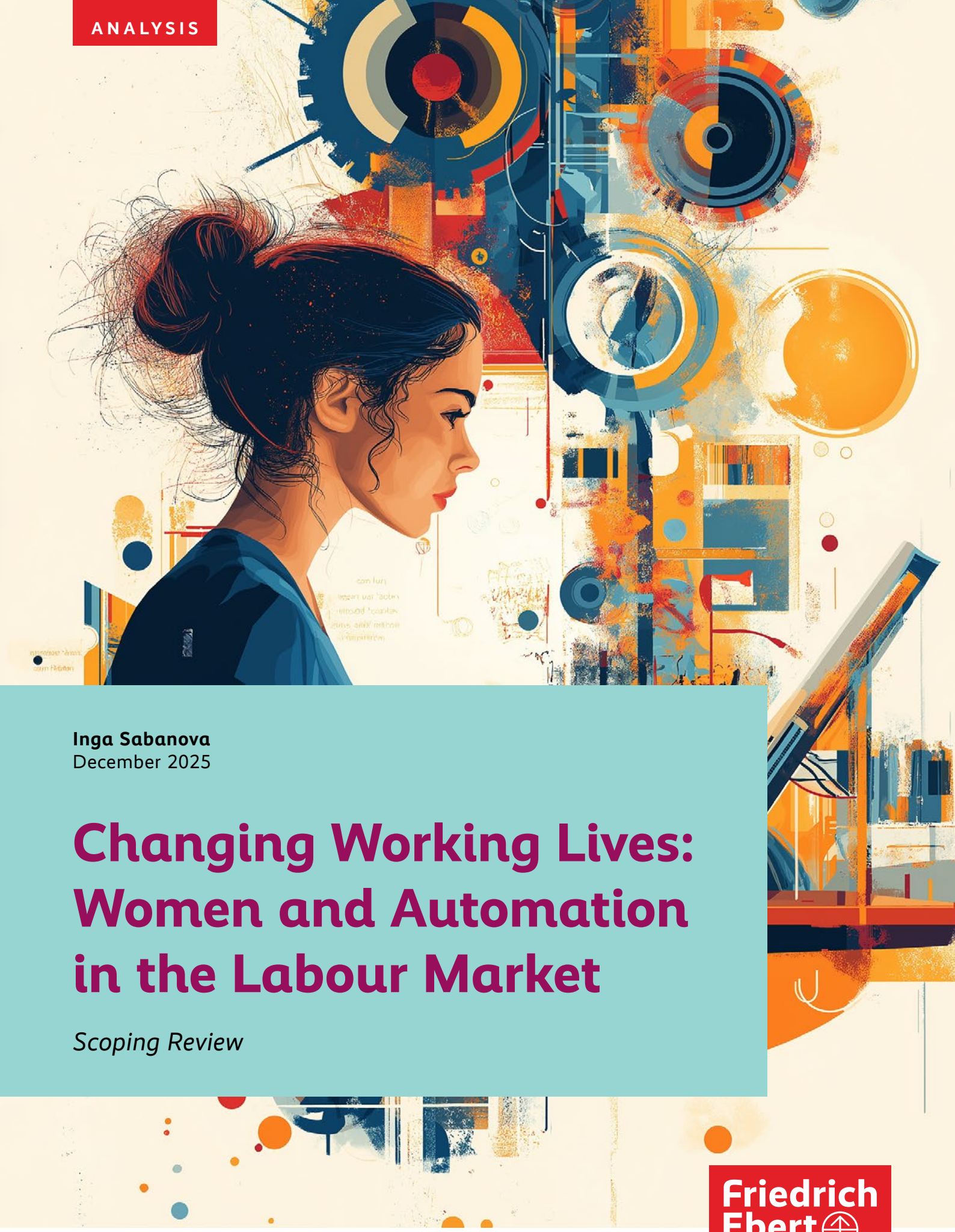

Inga Sabanova
December 2025

Changing Working Lives: Women and Automation in the Labour Market

Scoping Review

Friedrich Ebert Stiftung

Competence Centre on the Future of Work

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Summary

This paper takes a policy-oriented approach. It draws on evidence from peer-reviewed research, policy reports and 'grey literature' to examine the potential impact of automation on women's participation in the labour market. This important topic has largely been overlooked in current policy debates. The paper analyses how the existing literature address the impact of automation, particularly at the intersection of gender and labour market dynamics, and in relation to structural and systemic barriers that sustain gender disparities. It also identifies emerging themes that policymakers should prioritise when considering the gendered dimensions of automation and their implications for the future of work.

Based on a scoping review, the paper maps current research trends and highlights key limitations that require further attention from academic researchers. This will enhance our understanding of changing working conditions and inform policymaking. It focuses on four critical themes: workers' adaptability within the framework of workplace automation; gender employment and wage gaps in relation to technological change; the relationship between automation technologies and occupational safety and health, with particular attention to how women may be subject to new risks; and the implications for an ageing workforce in the context of technological change.

Introduction

This paper adopts a policy-oriented focus, drawing on evidence from peer-reviewed research, policy reports and grey literature in an attempt to shed light on the potential impact of automation on women's participation in the labour market. This is a topic that has largely been overlooked in current policy debates. The starting point of the analysis is the assumption – introduced by Frey and Osborne (2013) and repeated in numerous forecasting studies in the past decade – that automation in the workplace will inevitably affect the composition of the labour market, given the proportion of jobs likely to be automated in the near future (Arntz et al. 2017; Manyika et al. 2017). While both women and men will increasingly face similar challenges in managing transitions across occupations, women are more likely to be threatened by automation, even though men outnumber women in the workplace. This is because of existing segregation in the labour market.

This disparity is attributed largely to gendered differences in the nature of work. Women across occupational categories are more likely to perform routine and repetitive tasks (Piasna and Drahokoupil 2017). Nevertheless, the future paths of automation remain uncertain, as do the specific ways in which women may experience its effects, taking into account variations across industries, welfare regimes, individual trajectories shaped by access to retraining opportunities, and broader socio-economic inequalities.

Given these uncertainties and the different ways in which women may be affected, it is clear that any attempt to address gender disparities in the labour market requires more than broad policy commitments. Specifically, efforts to advance gender equality must be closely aligned with changing labour market dynamics, including the development and adoption of new technologies. In this way, progress may be achieved without compromising productivity or economic competitiveness.

The main research questions addressed in this paper, going beyond general observations on the gendered labour outcomes of technological change, are as follows:

(i) How does the existing literature tackle the impact of automation technologies on women, particularly at the intersection of gender and labour market dynamics, and in relation to the structural and systemic barriers that sustain gender disparities?

(ii) What emerging themes should policymakers prioritise when considering the gendered dimensions of automation and their implications for the future of work?

Based on the scoping review, the paper maps out current research trends, as well as some general limitations that require greater attention to attain a more comprehensive understanding of changing working conditions, particularly for future policymaking. Automation, which includes the applications of AI systems, robotics and algorithmic management systems, is a relatively recent phenomenon. Thus, there is a significant lack of research on how these technologies may impact the work environments of diverse population groups.

After the introduction, a literature review examines the relationship between automation and gender equality in the labour market, considering the interplay between technological change, labour market dynamics and gender inequalities. This is followed by a section on methodology and analysis. The subsequent four sections focus on key trends identified in the literature, highlighting its limitations and identifying potential areas for further research, particularly those that could inform the policymaking process.

As research and policy become increasingly interconnected, this paper proposes that researchers focus on four key themes that require further exploration to inform future policymaking. These areas are critical for developing detailed and actionable proposals, particularly for European policymakers.

The first theme is workers' adaptability in the context of workplace automation. It is clear that an exclusive focus on individual capabilities, treating gender as merely one socio-demographic variable among others, would be insufficient to capture the complexity of different sectors, as well as the differences between the EU Member States. The institutional context is central in shaping la-

bour market outcomes and must be incorporated into any analysis. In particular, welfare regimes and industrial relations systems shape gender regimes at both the European level and within individual EU Member States. Their influence is crucial when evaluating the implications of technological change for women's employment trajectories.

The second theme is gender employment and wage gaps amid technological change. While emerging technologies reshape work and wages across all sectors of economy, research often focuses on Science, Technology, Engineering, and Mathematics (STEM) and manufacturing, which are largely male-dominated sectors. Services or the health and care sector, which are female dominated, tend to be overlooked. Empirical studies largely address industrial robots, neglecting other types of technologies, including AI in health care, education and administration. Addressing these gaps is essential to ensure that technological progress supports rather than undermines gender equality in the labour market.

The third theme is the relationship between automation technologies and occupational safety and health (OSH), with particular attention to how women may be subject to new risks. The health impacts of automation are rarely analysed through a gender-sensitive lens, despite evidence that women and men face distinct physical and psychological hazards as a result of differences in job roles, societal responsibilities and expectations. Gender bias in robotics and data-intensive technologies can exacerbate psychosocial risks in particular, whether through physical design, such as equipment tailored to the average male, or through algorithmic design based on unbalanced historical datasets.

The fourth area of concern is the implications for an ageing workforce in the context of technological change. The demographic shift in Europe is giving rise to significant economic challenges, but no comprehensive framework exists to address the dual pressures of extended working lives and persistent ageism. This applies in particular to older women, who represent the fastest growing segment of the workforce. Older workers often face conflicting pressures. Alongside policies that promote prolonged employment they are also subject to workplace barriers and face pressures toward early retirement. Addressing these gaps is essential to ensure that technological and demographic transitions support age-inclusive and gender-inclusive labour market participation.

Background

Debates on the nature of technological progress and its impact on the economy and society are far from new (Schumpeter 1943). However, the 2013 study by Frey and Osborne brought these discussions back into focus, highlighting that the emerging wave of technological innovations can drastically reshape the future of work. Their estimates suggested alarming rates of job losses as a result of automation over the next decade.

Since then, the long-standing question posed by business leaders, policymakers, journalists and academics has focused predominantly on the uncertainty surrounding the pace and scale of the rollout of automation technologies. However, in efforts to grasp the vast changes across the economy and society, especially because of the predicted 'technological unemployment' (Keynes 1930), little consideration has been paid to the gendered impact of automation, including how technological changes may disproportionately affect women's participation in the labour market and perpetuate existing inequalities.

Automation in the workplace

While automation itself is not a recent phenomenon, the form of automation that relies on AI systems, robotics, and algorithmic management is relatively new. The Industrial Revolution was a major turning point for industrial automation. Machines such as the 'spinning jenny' and the power loom replaced manual labour with mechanised production. Another key moment in automation was Henry Ford's assembly line, which made manufacturing more efficient by breaking up tasks into simple, repetitive steps (Sanka 2023).

Today, automation involves a wide range of technologies, ranging from robotics and artificial intelligence to software and interconnected devices, to perform tasks previously carried out by humans, encompassing both physical and cognitive functions. Advanced robotics can further transform manufacturing or warehousing, while AI and algorithmic systems are expected to intensify automation across sectors such as health care, education and finance. The main difference in comparison to previous waves of automation is that machines – both hardware- and/or software-based – are becoming more autonomous and are able to 'learn' for the first time (Khogali and Mekid 2023).

Although automation is anticipated to significantly impact employment and economic structures, it may also present opportunities to create new roles, minimise hazardous work and enhance overall quality of life. Many experts argue that, consistent with historical trends since the Industrial Revolution, each wave of automation will inevitably displace certain jobs, while simultaneously increasing the complexity of tasks and evolving job roles. It is claimed that this will allow many workers to focus on more strategic and creative responsibilities while reducing the time spent on manual, administrative, or repetitive work.

In terms of the current functioning of the economy, production and labour, the process of automation tends to

start with a pilot project, with the aim of streamlining and workflow automation. The goal of automation lies in performing tasks without or with minimised human involvement. This applies in particular to repetitive manual tasks, tasks that are duplicated across various workflows, tasks that require unnecessary communication, or tasks that are time sensitive or urgent. Examples of automation can be found across nearly all sectors of the economy, from retail and transportation to advanced manufacturing and construction. These include a range of cognitive and non-cognitive tasks in decision support, predictive maintenance, customer support and relationship management, email management, information retrieval and knowledge management (Schlögl et al. 2019).

In theory, automation should lead to a shift in job roles, requiring workers to acquire new skills and collaborate with machines in innovative ways, as automation's capacity to replace or complement workers across an ever-broadening range of tasks continues to increase (EIGE 2020). There may be numerous benefits from automation, ranging from improving worker's efficiency, productivity and well-being to enabling a more flexible and dynamic way of working (Manyika et al. 2017). First, automation technologies can increase efficiency by eliminating human error and reducing the time required to complete tasks. Second, robots and AI systems deployed in hazardous environments can mitigate the risks to human workers. They can perform tasks that are physically demanding, repetitive or dangerous, reducing workplace injuries and improving overall safety. Thirdly, automation allows organisations to scale operations without a proportional increase in human resources. Machines can handle repetitive tasks, potentially freeing up human workers to focus on complex problem-solving, creativity and innovation. Finally, while the initial investment in automation technology can be significant, the long-term cost savings can be substantial. Machines can perform tasks at a lower cost, with reduced labour expenditure and increased operational efficiency (Artik 2023).

However, as technologies continue to evolve and are used for purposes beyond the enhancement of productivity and safety, there are numerous examples of automation being employed as a tool of digital tracking, monitoring and surveillance (European Parliament 2020). This raises doubts about the real intentions behind data-saving technology in the workplace. As Winner (1980:121) reminds us, 'the machines, structures, and systems of modern material culture can be accurately judged not only for their contributions of efficiency and productivity, not merely for their positive and negative environmental side effects, but also for the ways in which they can embody specific forms of power and authority'. Technology needs to be understood as a socio-technological and political process rather than as a merely neutral tool. Workplace automation thus requires a more critical evaluation, taking into account 'the mutual constitution of technological and social relations that shape how, why, and under what conditions new technologies come into being' (Kelly 2022: 141).

The future of work for women

Although prognoses vary (Frey and Osborne 2017; World Economic Forum 2016; OECD 2016; PwC 2019), most experts are consistent in their conclusion that automation technologies in the workplace will inevitably affect the composition of the labour market based on the proportion of jobs likely to be automated in the near future. While both women and men will increasingly face similar challenges in managing transitions across occupations, women are more likely to be threatened by automation because of the differential occupational distribution arising from existing gender based labour segregation. Gender segregation in the labour market can be attributed to various factors, including biological differences, unequal investment in education and training, differing income roles, societal preferences and prejudices, socialisation, stereotypes, entry barriers and organisational practices (OECD 2023). These structural and cultural barriers shape occupational choices and career trajectories across labour market sectors, frequently restricting opportunities for women.

Gender segregation in the labour market encompasses both horizontal and vertical forms of segregation. Horizontal segregation can be broadly defined as the concentration of men and women in different kinds of jobs. Horizontal segregation in practice means that women are typically over-represented in sectors or occupations that tend to offer lower rates of pay. They also require skill levels that are rated lower than those required by sectors and occupations in which men are over-represented. Vertical segregation refers to a situation in which opportunities for career progression are limited for a particular gender within a company or sector. This can contribute to a range of gender-related inequalities, such as a gender pay gap. The unequal distribution of female and male workers across and within job types remains a striking and persistent feature of modern labour markets (Das et al. 2019). Despite policy efforts to promote gender equality in the labour market, the gender composition of employees varies between hierarchical levels within and between firms. Based on the 2021 European Working Conditions Telephone Survey (EWCTS), more than half of the working population in the EU still work in occupations dominated by their own gender. Men continue to have more 'power' in the workplace, being more likely to occupy the role of line manager than women: two-thirds of employees had a male boss in 2021 (McCaughey 2023).

Overall, projections on the future of work for women have so far followed three main lines of discussion. First, women are disproportionately represented in the performance of routine tasks, which, research suggests, are more vulnerable to automation (Autor et al. 2003). Second, while women are concentrated in sectors such as health care, education and social assistance, which are less likely to be automated, they tend to offer lower pay and poorer working conditions. Third, women remain

significantly underrepresented – and in many cases are excluded – from high-growth STEM fields that are expected to drive the development of automated technologies and the future of work (WGEA 2020). Together, these developments suggest that while women may face lower immediate risks from automation, structural inequalities continue to limit their access to high-quality, better-compensated opportunities in the emerging technology-driven economy.

Methodology

It was decided that a scoping review would be the most appropriate methodological tool as the main purpose of this study is an overview of the literature. The aim is to not only to identify knowledge gaps and look at the scholarly work on the relevant topics, but also to map, report and discuss emerging concepts and characteristics in the academic, policy and grey literature. Unlike systematic reviews, which seek to collate all the empirical evidence that fits the specified eligibility criteria concerning a given research question, a scoping review serves an exploratory purpose, searching, selecting and synthesising existing knowledge (Gutiérrez-Bucheli 2022). It also maps the research landscape and identifies conceptual developments and areas of uncertainty (Anderson et al. 2008). Scoping reviews are useful for examining emerging evidence when it is still unclear what other, more specific questions might be posed and valuably addressed by a more precise systematic review.

A scoping review adheres to the framework proposed by Arksey and O'Malley (2005), consisting of a five-step process, summarised in Table 1.

The starting point for formulating the research questions is relevant studies, primarily forecasting research, described in the background section of this paper. These studies argue that automation technologies in the workplace will inevitably affect the composition of the labour market, based on the proportion of jobs likely to be automated in the near future. Women are more likely than men to be negatively affected as a result of existing labour market segregation.

The main research questions were formulated on this basis:

i. How does the existing literature tackle the impact of automation technologies on women, particularly at the intersection of gender and labour market dynamics, and in relation to the structural and systemic barriers that sustain gender disparities?

ii. What emerging themes should policymakers prioritise when considering the gendered dimensions of automation and their implications for the future of work?

Specifically, with regard to the future of work within and across different sectors, how does the literature address the fundamental components of work, such as wages, the organisation of tasks, workplace design, career progression, promotions and discrimination in the context of automation?

A comprehensive search was conducted across multiple electronic databases, including Scopus, Web of Science, and ScienceDirect, supplemented by grey literature from Google Scholar, EU institutions, and European Commission-funded projects accessed via Cordis. In addition, outputs from international organisations, such as the UN, the ILO and the World Bank, alongside reports from think tanks and business consultancies, were examined to ensure a wide-ranging and inclusive evidence base.

To guide the search, a detailed search protocol was developed specifying inclusion and exclusion criteria, search terms and screening procedures. The inclusion criteria focused on literature published between 2019 and 2024, encompassing academic peer-reviewed publications, reports and working papers, with a focus on English-language sources and a particular focus on

Table 1

Framework proposed by Arksey and O'Malley (2005)

1	**Identifying the research question**	The process begins with formulating an overarching question to guide the search strategy
2	**Identifying relevant studies**	A comprehensive and systematic search strategy is designed to capture a wide range of sources and ensure robust coverage of the relevant evidence base.
3	**Study selection**	Predefined inclusion and exclusion criteria are developed in advance, but remain subject to refinement as familiarity with the literature deepens.
4	**Charting the data**	Key information is extracted from selected studies and organised thematically, allowing for the identification of patterns and conceptual trends.
5	**Collating, summarising and reporting results**	Findings are synthesised and presented as a narrative, reflecting the complexity and diversity of the reviewed materials.

European countries. Search terms included a variety of keywords, such as 'automation', 'AI', 'robotics', 'women', 'gender', 'discrimination', 'workplace', 'skills', 'transition', 'EU', and 'equality'; these represent only a subset of the many terms used, reflecting the interdisciplinary and intersectional focus of the study. Studies examining labour market dynamics primarily in non-EU contexts were excluded from the review.

The review process followed a two-stage screening approach. First, titles and abstracts were reviewed for relevance against the inclusion criteria. Second, a full-text review was conducted on shortlisted studies to confirm their alignment with the research questions. An Excel spreadsheet was used systematically to document the details of each included study, recording information such as publication type, authors, year, title, journal, keywords and abstracts.

Key themes and concepts were extracted from the selected literature and organised into analytical categories. Although the primary focus was on literature explicitly addressing women and automation, the review also incorporated studies that, while not solely focused on women, contributed valuable insights into the gendered dimensions of automation and labour market dynamics.

In total, an initial pool of 1,020 sources was identified. Following the screening process, 600 studies were reviewed, and ultimately 65 studies were included in the final analysis. The findings are presented in a narrative synthesis, mapping the main concepts, sectors and geographical regions covered in the literature. This comprehensive approach allowed for a detailed exploration of how the topic has been conceptualised and addressed across the scholarly and grey literature, providing a robust foundation for identifying critical gaps and future research directions.

Overview of the key research areas

An examination of the collected sources reveals that job displacement remains a central concern. There has been considerable research into the potential scale of workforce disruption, nationally and internationally. Nevertheless, gender-focused analyses are relatively scarce, and the findings that have been obtained are often inconclusive. This is partly because of a tendency to overgeneralise global trends without accounting sufficiently for the specific complexities of the European market. Automation does not occur in isolation but is shaped by institutional contexts, including gender equality in employment and education within the European Union, as well as the influence of welfare regimes and industrial relations systems. The evidence base is further constrained by its limited and inconsistent coverage across technological domains, sectors and industries. Many studies overlook regional variations, such as rural–urban disparities and firm-level differences, which are crucial for capturing the full impact of automation on workers, both men and women. To address these gaps, incorporating an intersectional approach is essential to understand women's diverse experiences across EU Member States and sectors. Particularly valuable in this respect are mixed-method designs that integrate qualitative case studies for a nuanced, context-specific understanding of women's experiences.

Analysis of the collected research papers has identified four key themes concerning automation technologies and their potential impact on women's participation in the labour market.

The first concerns workers' adaptability in the context of workplace automation. However, an exclusive focus on individual capabilities, with gender treated merely as one socio-demographic category among others, is insufficient to capture the complexity of different sectors, as well as the differences between EU Member States. The institutional context is central in shaping labour market outcomes and must be incorporated into any analysis. In particular, welfare regimes and industrial relations systems shape gender regimes both at the European level and within individual EU Member States. Their influence is crucial when evaluating the implications of technological change for women's employment trajectories.

The second examines gender employment and wage gaps in the face of technological change. While emerging technologies reshape work and wages, research often focuses on STEM and manufacturing, overlooking the service and care sectors, which are female-dominated. Empirical studies largely address industrial robots, neglecting other types of technologies, including AI in health care, education and administration. Addressing these gaps is essential to ensure that technological progress supports rather than undermines gender equality in the labour market.

The third topic is the relationship between automation technologies and occupational safety and health (OSH), paying particular attention to how women experience new risks. The health impacts of automation are rarely analysed through a gender lens, despite evidence that women and men face distinct physical and psychological hazards because of differences in job roles, societal responsibilities and expectations. Gender bias in robotics and data-intensive technologies can exacerbate these risks, whether through physical design, such as equipment tailored to average male dimensions, or through algorithmic design based on unbalanced historical datasets.

The fourth examines the implications for an ageing workforce in the context of technological change. The demographic shift in Europe is leading to significant economic challenges, but no comprehensive framework exists to address the dual pressures of extended working

lives and persistent ageism, particularly with regard to older women, who represent the fastest-growing segment of the workforce. Older workers often face conflicting policies that promote prolonged employment while simultaneously encountering workplace barriers and pressures toward early retirement. Addressing these gaps is essential to ensure that technological and demographic transitions support inclusive and gender-inclusive labour market participation.

1. Adaptability, skills and fear of automation

Most of the selected studies examine individual perceptions of technological change and willingness to adapt to the emerging risks associated with automation, particularly in relation to unemployment, job mobility and the need to acquire new skills. This research does not focus specifically on women in the labour market and therefore does not provide clear evidence of potential gender differences based on different sectors and job profiles. Nonetheless, it remains important as it highlights the complex interplay between contextual and individual factors that potentially can be valuable also for understanding women's career trajectories.

Across all studies, the authors consistently find that the transition towards an automated work environment is often associated with feelings of insecurity, fear and resistance to change, especially among people employed in occupations most vulnerable to automation. As a result, numerous studies highlight that perceptions of these changes are strongly influenced by psychological factors, which are themselves shaped by demographic characteristics such as education, age, gender, ethnicity, place of residence, and perceived economic well-being (Ivanov et al. 2020). The research does not focus specifically on women in the labour market and therefore does not provide clear evidence of potential gender differences.

For example, studies with a comparative macro focus do not show significant effects of gender differences, especially when respondents' other demographic characteristics, such as education, age, gender or level of income are considered. Innocenti and Golin (2022) find that women, younger workers and those on low incomes are more likely to be worried unemployment resulting from automation. Similarly, using survey data from six Central EU countries – Austria, Czechia, Germany, Hungary, Poland and Slovakia – Włoch et al. (2025) demonstrate with reference to previous studies that exposure to technology increases fear of automation, as well as fears surrounding task substitution and the potential elimination of routine work. They also find that younger, less-educated and lower-income individuals, along with those who feel they lack control, are more afraid of automation. However, gender does not have a significant effect.

Similarly, the analysis, based on data from the Socio-Economic Panel Study (SOEP 2015–2017), indicates some heterogeneous automation risks for men and women among female-dominated and mixed gender occupations. Golsch et al. (2020) show that in female-dominated occupations, women are less likely than men to experience changes, but in mixed gender occupations they seem slightly more likely to do so than men. This may be explained partly by the lower likelihood of automation in female-dominated occupations. As a result, concerns and perceptions of automation-related risks may be less pronounced among women working in these sectors.

However, fears that machines may replace human labour, leading to unemployment and economic insecurity, are expressed differently across sectors and occupations, but they do not arise in isolation. Research shows that workers' awareness of technological change is closely connected to concerns about precarious working conditions. Włoch et al. (2025) argue that workers become more conscious of the potential of automation when they encounter such technologies in the workplace, even when these tools merely complement their tasks. This suggests that the presence of automation, regardless of its specific function, prompts workers to reflect on its broader implications for job security. However, such fears do not originate solely from the introduction of new technologies. Any discussion of technology must also be situated within longer-term labour market trends that have been unfolding over time.

Deruelle et al. (2024) in their research demonstrate that these fears might derive not only from the possibility of technology changing workers' tasks, but also from how technological change can lead their industries to introduce more alternative work contracts, gig work, working for multiple employers, part-time work and short-term contracts. Based on the OECD survey carried out in 25 countries, the authors show that most people expect an increase in non-standard work arrangements. Specifically, the research demonstrates a correlation between labour market environments and social indicators, such as levels of unemployment spending or labour market spending. For example, technological advancements make people in countries such as Austria, Belgium and Germany feel less threatened by alternative work contracts, but respondents envision a more imminent turn to non-standard work forms in countries such as the USA, Turkey, Portugal, Poland or Greece.

Indeed, the evidence indicates that workers' capacity to adapt to automation can be shaped by a combination of individual characteristics and broader contextual factors. Technology does not emerge out of nowhere; rather, it is introduced through a complex and often ambiguous process involving technological adoption, changing labour conditions, such as introducing short-term contracts, and other factors that may contribute to workers' discomfort with technological advancements. As Fleming (2019) ar-

gues, technology is *bounded* by social-organisational forces which mediate whether a job or task is automated or not based on different considerations, such as the price of labour, levels of unionisation and nature of the task (Fleming 2019 in Kelly 2022).

While workers are often seen as the primary agents experiencing or anticipating workplace transformations as a result of technology, the implications of automation are equally a concern for businesses trying to innovate. Concerns over loss of control and uncertainty about the future labour market can, in turn, create additional challenges, as worker resistance may heighten organisational uncertainty, complicating efforts to remain competitive and successfully integrate technological advancements.

Beyond the dominant narratives that frame 'artificial intelligence' as a solution to future challenges, Schlögl et al. (2019) note that organisations are still only in the early stages of adopting and integrating AI tools and technologies. Their research consistently highlights the presence of substantial organisational barriers to successful implementation, primarily a lack of employee acceptance. Findings from their qualitative study indicate that workers often report insufficient knowledge and information, heightened fear of job displacement – especially in relation to routine and repetitive tasks – and scepticism regarding the notion that job losses in certain sectors will be offset by the creation of new employment opportunities in others. These concerns point to the importance of strengthening worker readiness and ensuring that automation is introduced in ways that safeguard their prospects and working conditions.

On the other hand, even if workers are assumed to act as rational agents capable of mitigating the risks of automation by acquiring new skills, this perspective remains somewhat simplistic. Peneder et al. (2016) argue that transitions from manual to non-manual occupations may create opportunities for persons on education paths vulnerable to automation to advance within the occupational hierarchy. However, such opportunities are unevenly distributed, and structural constraints – particularly limited access to training and skill development – often hinder workers from maximising opportunities on new career paths.

Heß et al. (2023), using the example of a highly automated sector such as manufacturing and drawing on the National Educational Panel Study (NEPS) data on workers' educational and labour market trajectories between 2009 and 2020, find that workers in occupations with high exposure to robot technology participate in significantly less training, even after controlling for worker, job and firm characteristics. Those workers who transition from high-exposure to lower-exposure occupations tend to increase their training participation, whereas workers who become unemployed do not. The training gap is particularly pronounced for men and medium-skilled workers with apprenticeship qualifications, especially in information and communication technology (ICT) and soft or business skills courses. Furthermore, employees in high-exposure occupations receive substantially less financial and non-financial support from their firms, and the overall training gap is driven primarily by firm-financed training opportunities.

Similarly, using the Programme for the International Assessment of Adult Competencies (PIAAC) microdata from 14 European countries, Ioannidou and Parma (2021) show that while welfare regimes differ in the support they provide for workers' participation in job-related adult education and training (AET), workers in high-risk occupations are consistently less likely to participate, regardless of gender, age, education, employment status or welfare regime. Participation rates are highest in Scandinavia (55 per cent), followed by the Anglophone countries (50 per cent), and lowest in Southern Europe (29.5 per cent), with Continental (42 per cent) and Central and Eastern European (34 per cent) countries in between.

Moreover, in understanding workers' access to retraining and skill development opportunities, it is crucial to consider contextual factors beyond the national level, as regional differences and the concentration of specific industries in certain areas can significantly shape labour market outcomes. Notably, regional variations and the rural–urban divide are key determinants that need to be studied more fully in future research, given that opportunities for occupational mobility and skill upgrading are often concentrated in metropolitan areas. For example, evidence from Swedish panel data demonstrates that large cities reduce automation risks primarily through job mobility across firms. In particular, metropolitan labour markets provide greater opportunities for upward career transitions, enabling workers to move into less automatable jobs. These benefits are not evenly distributed, however: they are strongest for high-skilled male workers with college degrees, who are more likely to profit from networking and knowledge exchange in urban areas. By contrast, women, lower-educated workers and immigrants gain far fewer advantages from these dynamics (Czaller 2021).

In a similar vein, contextual factors shape individual strategies for acquiring new skills, which in turn influence job mobility both within and across firms and sectors. Evidence from German local labour markets show that while industrial robots displace manufacturing jobs, these losses are fully offset by new employment opportunities in the service sector. The negative effects are most pronounced for young labour market entrants, who adapt by shifting from vocational training toward higher education (Dauth et al. 2021).

To conclude, the existing literature on workers' adaptability in the context of workplace automation provides valuable insights but remains limited when it comes to

addressing women's specific position in the labour market. While much of the scholarship recognises the importance of socio-demographic characteristics, a more systematic focus on gender, in combination with age, migration background and educational attainment, is still required, ideally through mixed-method approaches. Applying an intersectional lens is crucial for understanding how these factors interact to shape women's employment trajectories across sectors and occupations. Without such nuanced data, future policymaking risks reproducing generalisations that obscure structural inequalities and reinforce the uneven distribution of opportunities, particularly for women, who are frequently underrepresented in labour market analyses.

Technology itself is embedded in wider social and economic processes, and its integration into workplaces cannot be viewed in isolation from long-term trends such as deregulation and shifts in working conditions. Workers' concerns extend beyond the fear of technological displacement to encompass broader labour market dynamics, including precarious employment, short-term contracts and declining job security. These conditions demonstrate that adaptability is unevenly distributed and closely connected to existing structural inequalities, highlighting the need for policies that account for these intersecting factors.

Finally, access to retraining and upskilling opportunities is unevenly distributed, often limiting workers' capacity to seize new career paths. Access varies across sectors, the availability of firm-provided training, welfare regimes, and regional or rural–urban contexts, which further compounds inequality. Understanding these structural and contextual factors is essential for designing interventions that genuinely enhance workers' adaptability.

2. Gender employment and wage gap

The second theme identified in the reviewed literature concerns gender employment and wage gaps in the context of technological change. This theme is particularly important, as emerging technologies have the potential to reshape employment patterns, wage structures and workplace dynamics. The studies included in the scoping review raise critical policy questions about how to ensure that technological progress supports, rather than undermines, gender equality in the labour market, particularly given persistent disparities across the European Union. Despite gradual improvements in women's employment and representation, progress has been slow. In 2023, the EU gender employment gap remained at 10.2 percentage points, while women's gross hourly earnings were, on average, 12.0 per cent lower than men's (Eurostat 2025), highlighting the continued vulnerability of gender equality to labour market changes.

Whereas the previous section reviewed studies that did not explicitly address women, the research discussed here adopts a more critical and nuanced perspective by placing women at the centre of the analysis. This literature nonetheless reveals notable imbalances in research focus. Debates on the gender employment gap are often situated within policy discourses that emphasise the importance of increasing women's participation in STEM fields. However, scholars increasingly argue that closing the gap requires not only expanding women's access to these fields but also transforming organisational cultures to enable women to build and sustain successful careers.

By contrast, studies on the gender wage gap remain disproportionately concentrated in manufacturing contexts. Much of the empirical work has examined the impact of industrial robots, while giving limited attention to the expanding role of AI and robotics in female-dominated sectors. This neglect is problematic in light of the growing use of AI-enhanced service robots and collaborative robots (cobots) in health care, care work and administrative services, sectors that employ a predominantly female workforce.

Despite these limitations, this body of research highlights the significant role of institutional and contextual factors, including structural barriers, workplace culture and organisational norms, in shaping how technological change affects gender inequalities in employment and wages, while not fully determining them.

In examining the gender employment gap, much of the discussion has centred on women's persistent underrepresentation in STEM fields. These debates often stress the importance of developing the skills that would enable more women not only to enter these areas but also to succeed within them.[1] Only two out of five scientists and engineers are women, and in the ICT sector, they make up just 17 per cent of nearly eight million specialists (EIGE 2025). The imbalance is even more pronounced in the start-up ecosystem, in which women remain a small minority of founders and leaders, limiting their influence on the development of new technologies and business practices.

Addressing this imbalance is therefore not only a matter of equality but also of economic opportunity (Serrano et al. 2023). Closing the gender gap in STEM education could strengthen the EU economy while fostering greater innovation. Research demonstrates that organisations led by female CEOs are more likely to engage in creative and forward-thinking activities, and are more prone to adopt en-

1 For example, Google has increased its overall hiring of women, but they occupy less than a quarter of technical roles. A similar pattern exists at Apple, where only a small proportion of women hold technical and leadership positions. Comparable trends are seen at Amazon, Facebook and Microsoft, while in Asian firms such as Samsung and Huawei, women make up just a tiny fraction of management and executive teams (Serrano et al. 2023).

vironmentally sustainable practices (Khushk et al. 2022). These findings highlight the broader benefits of including women in leadership positions: when women shape decision-making, organisations tend to pursue strategies that are both innovative and socially responsible.

This is particularly relevant in emerging fields such as artificial intelligence, encompassing professions such as machine learning or robotics engineers, data scientists and software developers. As Leavy (2018) explains, »leading thinkers in the emerging field addressing bias in artificial intelligence are also primarily female, suggesting that those who are potentially affected by bias are more likely to see, understand and attempt to resolve it. Gender balance in machine learning is therefore crucial to prevent algorithms from perpetuating gender ideologies that disadvantage women« (Leavy 2018: 14). In other words, achieving workforce diversity is not simply a matter of increasing the number of women; it requires transforming organisational culture and governance so that women can exercise real influence over technology and innovation (Wajcman and Young 2023).

In supporting this argument, a review by Dabić et al. (2024) of 108 articles with a focus on women in engineering shows that applying the glass ceiling theory as an analytical framework reveals a persistent neglect of women's experiences and the structural barriers embedded in the engineering profession. The review further concludes that increasing female participation alone is insufficient; instead, comprehensive and targeted policy interventions are necessary to establish conditions in which women can not only enter the field but also progress, exercise leadership and contribute substantively to technological innovation (Dabić et al. 2024).

The transition from STEM studies to STEM employment represents a critical moment in shaping long-term career trajectories. Evidence shows, however, that women face structural disadvantages during this stage, which can hinder both retention and advancement in the sector. Recent research from Spain (Valdés and Solga 2024) further highlights the challenges women face when embarking on STEM careers. Being female significantly reduces the likelihood of securing a first job in STEM following completion of a bachelor's degree. This disadvantage is evident across all STEM subfields, but is especially pronounced in mathematics and technology. Importantly, these gender differences persist regardless of the proportion of women in each field. Over time, the gap widens: women who begin their careers in STEM are less likely than men to remain in STEM roles four to five years after graduation. Although women are no more likely than men to leave their first job, when they do transition, they are at greater risk of exiting the STEM sector entirely. These dynamics have two major implications. First, they represent a loss of highly skilled workers for sectors critical to innovation and economic growth. Second, they directly contribute to the gender pay gap, as women who exit STEM roles often earn less in non-STEM occupations.

The challenges observed in STEM fields have broader parallels in many academic fields, where women are significantly more likely than men to leave academic or research positions (Naddaf 2025). Structural barriers, workplace culture, limited opportunities for career progression and the prevalence of precarious fixed-term contracts contribute to these patterns, creating a »research precariat« that disproportionately affects women and early-career researchers. This gender gap in earnings persists across all science areas and is widest in the physical sciences, where women earn up to 11 per cent less than their male counterparts (OECD 2021). These conditions highlight once again that simply increasing female participation is insufficient; meaningful change requires transforming the existing culture and employment structures to ensure long-term engagement, career stability and equity.

Improving gender equity involves not only bringing more women into STEM, but also addressing disparities across other sectors. As Moss-Racusin et al. (2022) have argued, society tends to express less concern over men's underrepresentation in such sectors as health care, early education and domestic work than over women's underrepresentation in STEM. This asymmetry reflects broader gender hierarchies, including the devaluation of work traditionally done by women and the assumption that men freely choose to avoid low-status fields, whereas women are actively excluded from high-status STEM roles. This lack of attention to female dominated sectors with gender gaps is concerning, as men's underrepresentation has negative effects on men, women, children and society as a whole.

While gendered patterns of participation across sectors highlight asymmetries in how underrepresentation is problematised, research on technological change and wage gaps has concentrated largely on contexts that are male dominated. Within the European Union, the manufacturing sector has indeed been at the forefront of automation adoption, particularly in recent years through the deployment of technologies such as the industrial »internet of things« (IoT), big data analytics, artificial intelligence (AI), additive manufacturing and advanced robotics (Calza et al. 2024). Consequently, the bulk of research in this domain is concentrated in manufacturing, providing both national and cross-national perspectives. However, most scholarly work has focused primarily on the diffusion and impact of industrial robots, including their implications for gender wage disparities, confirming that robot integration tends to widen the wage gap.

For example, Aksoy et al. (2020), using data from 20 European countries, demonstrate that robot adoption has

uneven effects on earnings. While automation generates overall wage gains for both men and women, it simultaneously widens gender pay disparities, with a 10 per cent increase in robotisation associated with a 1.8 per cent expansion of the gender pay gap. Notably, rather than workforce composition changes driving the effect, it is most pronounced in countries with high pre-existing gender inequalities, where men in medium- and high-skilled occupations capture a disproportionate share of productivity gains. The impact is particularly evident in outsourcing destination countries, primarily in Eastern Europe, where both gender inequality and robotisation levels are high. In contrast, in outsourcing origin countries in Western Europe, where initial gender inequalities are lower, robot adoption has not significantly affected the gender pay gap. Countries such as the Czech Republic, Hungary, Italy, Poland and Slovakia, which are characterised by lower gender equality and high robotisation, are key contributors, whereas nations with higher gender equality, including Belgium, Germany, the Netherlands, Spain and Sweden, show little or no widening of the gap.

This finding highlights the crucial role of national institutional and policy frameworks in shaping gendered labour market outcomes. In Europe, wage levels and inequalities, including gender pay disparities, are strongly influenced by factors such as minimum wage policies, wage indexation, labour market liberalisation, unionisation and welfare state regimes, which shape both pay structures and broader social relations. This reinforces the earlier conclusion that it is not technology in itself, but its interaction with institutional and structural contexts that determines how technological change affects gendered labour market outcomes.

A similar conclusion has also been drawn by Fana and Giangregorio (2024), who argue that when it comes to explaining the polarisation of wage trends, an overly narrow focus on technology overlooks many important developments in wage structures that cannot be fully accounted for in terms of skill-biased technological change (SBTC). The authors show that structural and institutional elements – such as regulated labour markets, collective bargaining and statutory minimum wages – are especially influential in wage determination in countries such as France, where these frameworks are more developed, in contrast to Anglophone or Eastern European countries.

Within this context, the firm level is especially important for understanding the interplay between institutional frameworks and individual worker capabilities, as it is where technology is adopted, wages are set and inequalities – including gender pay gaps – emerge both between and within firms, influenced by factors such as size, trade, productivity, pay distribution and workforce composition. Domini et al. (2020), investigating the firm-level effects of automation on wage and gender inequality in the case of France, find that most wage dispersion is attributable to differences among employees within the same firm, rather than across sectors, firms or occupations, and that automation events do not materially alter this pattern of inequality. Wage differences are not predominantly driven by rent-sharing linked to productivity gains from automation and AI, but rather by the recruitment of new employees.

Taken together, these findings highlight the complex ways in which technological change intersects with structural and institutional factors. While automation and AI can boost overall wages, they also pose a risk of exacerbating existing inequalities, particularly in countries or sectors with high pre-existing gender gaps. More research is needed on the impact of technological change in female-dominated sectors, taking into account sector-specific realities, as well as structural and institutional factors that shape the gender wage gap.

In conclusion, the reviewed literature suggests that technological change interacts with structural, institutional and firm-level dynamics, producing uneven and gendered labour market outcomes. While automation can enhance productivity and wages, these benefits risk reinforcing existing gender disparities if underlying structural inequalities remain unaddressed. Future research should extend its focus beyond manufacturing and industrial robotics to include female-dominated sectors and adopt an intersectional perspective. Such an approach would enable a more comprehensive understanding of how technology shapes women's wage outcomes and labour market opportunities, while also addressing the structural barriers within male-dominated sectors. Importantly, this is not only about facilitating women's entry into fields such as STEM but also ensuring meaningful career progression once they are there.

3. Well-being in the workplace

Another recurring theme identified in the scoping review is the relationship between automation technologies and psychosocial risks within the framework of occupational safety and health (OSH), paying particular attention to how women experience these risks. However, most studies on the health impacts of automation rarely adopt a gender-sensitive perspective, despite evidence that women and men face distinct physical and psychological hazards in the workplace. These differences are associated with variations in job roles, societal responsibilities and expectations. Gender bias in robotics and data-intensive technologies in the workplace may exacerbate, particularly psychological risks, whether through physical design – such as equipment suited primarily to average male dimensions – or data design, including algorithms trained on unbalanced historical datasets (ILO 2024). Addressing these risks requires not only gender-inclusive design, but also a customisation process in which all workers are in-

volved in decision-making to ensure that the systems accommodate their specific needs and contexts.

The results of the European Working Conditions Survey (EWCS) indicate that both women and men in Europe experience negative effects on their mental and emotional well-being as a result of their jobs. Nearly 45 per cent of workers are exposed to risk factors associated with stress, anxiety and depression, which are the most frequently reported work-related health problems (Lorenzini et al. 2023). Despite increasing awareness of these psychological risks, workers remain highly vulnerable, particularly as automation expands across sectors. Yet only 43 per cent of workplaces conduct risk assessments related to the use of digital technologies, and just 42 per cent provide relevant training. This is particularly concerning given that more than 80 per cent of the workforce regularly relies on digital devices. While overall consultations with workers regarding the health and safety implications of digital technologies have been increasing – 35 per cent of workplaces reported engaging in such consultations in 2024, up from 24 per cent in 2019 (Nawrocka 2024; EU-OSHA 2024) – women may face particular risks that are often overlooked, as occupational safety and health (OSH) frameworks are not consistently gender-sensitive.

At present, most workers have limited direct experience of interacting with robots, which are found primarily in large manufacturing enterprises. In 2022, roughly one in five large EU companies used industrial robots for tasks such as welding or laser cutting, while only one in ten used service robots for activities such as surveillance or transport. Adoption rates among small and medium-sized enterprises (SMEs) are considerably lower, primarily due to the high capital investment required and the economies of scale needed to fully leverage the efficiency gains offered by robotic technologies (Riso and Adascalitei 2024).

Nonetheless, this trend is likely to shift as human–robot collaboration expands in workplace settings. With their advanced capabilities, robots and collaborative robots (cobots) can enhance workflows across many sectors, from transport and logistics to industries in which women are overrepresented, such as health care, customer service and home-based care. In theory, these technologies could contribute to healthier, safer and more productive workplaces. For example, robots can help to reduce heavy lifting and alleviate musculoskeletal strain, while AI-driven monitoring systems can detect early signs of fatigue, stress or emotional distress, enabling timely interventions.

In practice, however, the introduction of robots into workplace processes requires careful adaptation, regardless of whether systems are purchased externally or developed in-house. Successful integration depends on tailoring these technologies to the specific operational environment and allowing sufficient time to incorporate worker feedback. Embedding human factors into the design and customisation of robotic systems is therefore critical to their effective deployment (Riso and Adascalitei 2024). Just as one would not expect a »one size fits all« uniform or piece of protective equipment to suit every worker – recognising that women are not simply smaller men, and small men are not women – robotic systems must also be designed with attention to the diverse needs, abilities and contexts of their users (IUF 2019). When design, implementation and integration are not properly considered, autonomous and semi-autonomous robots risk generating new psychological stressors with gender-differentiated effects. These may include work intensification, heightened stress from ergonomic strain as a result of repetitive machine interactions along with diminished autonomy, and reduced job satisfaction or sense of purpose.

Importantly, when automation is introduced without sufficient consideration of work design and workflow organisation, it can exacerbate stress among employees who are already vulnerable due to structural inequalities such as gender, age, ethnicity or educational background. Lombardi, Monaco and Capece (2024) note that while workers are crucial in developing measures to prevent psychosocial risks, their psychological and physical well-being – as well as related training – are often treated as secondary concerns. Indeed, only 48.6 per cent of industries currently recognise workers as key contributors to the development of preventive strategies. This finding illustrates that technology is not merely about hardware or software, but also about the organisational environment in which it is embedded and the ways it is used by human workers. Nevertheless, prevailing approaches frequently prioritise the implementation of new technologies over reflection on their broader consequences. But Riso and Adascalitei (2024) remind us that many of the negative outcomes attributed to automation arise less from the technology itself than from organisational and managerial choices. Addressing these concerns therefore requires careful attention to work design, management practices and the meaningful involvement of workers in decision-making.

While there are still only a few long-term studies on the impact of robotics technologies in the workplace (Heinold 2023), emerging case studies indicate that, alongside reductions in physical risk, psychological risks can emerge or intensify, particularly in environments in which workers are subjected to heightened job insecurity or reduced autonomy. For instance, research from Germany shows that increased automation can adversely affect workers' mental health by heightening uncertainty about job stability and curtailing opportunities for personal achievement. Other studies suggest that the introduction of new technologies may narrow the scope for employee autonomy in production processes while expanding managerial control, thereby increasing stress and reducing en-

gagement (EC 2023). Heinold (2023) further identifies two levels of stress associated with the introduction of robots. Implementing a robotic system in the workplace may trigger higher stress levels and increase fears of job loss in the early stages. Both effects appear to decrease over time, raising the question of how workers expect robotic systems to impact their work, not only in the short term but also in the long term.

Beyond physical interactions with robots, workplaces are increasingly shaped by data-intensive technologies such as algorithmic systems and artificial intelligence. These tools bring both opportunities and risks for workers' mental and psychological well-being. While data-driven systems come with promises of efficiency, cost savings and enhanced decision-making, their expanding role in workplace processes can also perpetuate and even amplify existing societal biases, including gender inequality. Automated decision-making – from recruitment and onboarding to task allocation and performance evaluation – may negatively affect employees, with direct implications for their psychological health. Crucially, the effects of these technologies are driven by the variety of ways in which data is collected, stored and used. Ultimately, algorithmic and AI systems must be understood as workplace technologies that shape human experience rather than merely as neutral tools operating in isolation.

As with robotics, examining data-driven technologies highlights the importance of considering the social and ethical dimensions of technology design and deployment. »Designers must integrate a pluralistic, multidisciplinary and inclusive perspective from the outset: who will use (or be affected by) this system? Will it produce fair results for everybody? If not, what do I need to fix to correct the unfair results? How can the objectives of the tool (the results for which it should be optimised) be defined in order to ensure that they do not produce discriminatory results?« (Lacroix 2020: 16).

Recognising how gender biases can be embedded in training data and algorithms thus helps us to demystify the ways in which these systems produce unfair outcomes and sheds light on the complex interplay between technology and social inequality (Digital Future Society 2022; Chen 2023).

Research increasingly shows that gender bias can be embedded in both datasets and algorithms. Training data often reflect historical inequalities, while programmer choices and development processes can introduce further biases. AI systems that »learn« from such data – which reflect the fact that women or minorities have been underrepresented, underpaid or denied opportunities – risk perpetuating these disparities. Tackling this state of affairs entails deliberate design choices: algorithms follow objectives set by their creators, and poorly defined goals can produce outcomes that are not only inaccurate but also discriminatory (Lacroix 2020).

Lütz (2022), for example, argues that AI systems can generate both direct and indirect forms of gender-based discrimination, but current European legal frameworks are not fully equipped to address these complexities. Direct discrimination occurs when algorithms explicitly disadvantage individuals based on gender, whereas indirect discrimination arises when biases embedded in data or system design produce outcomes that disproportionately affect one gender. However, the existing legislative base is insufficient to address the gendered risks posed by AI, as it lacks explicit mechanisms to prevent discrimination or promote equality.

This is particularly problematic in the workplace, where algorithmic management – which refers to the use of computer-programmed procedures to coordinate labour input in the workflows (Baiocco et al. 2022) – increasingly influence recruitment, task allocation, performance evaluation and other key employment decisions. Cefaliello, Moore and Donoghue (2023: 198) argue that »algorithmic management systems represent a risk to occupational safety and health (OSH) on two grounds. Firstly, the impact of algorithmic management on managerial practices and work organisation can exacerbate existing risks, as well as create new ones, particularly when it comes to psychosocial risks. Secondly, the gathering of data necessary for the functioning of algorithmic management can also be a source of stress and anxiety due to the opacity of the systems, fear of and practices of real-time activities of constant surveillance, unpredictability of the software, new pressures on the psychological contract, mistrust, and pressures to overwork.«

In other words, without adequate safeguards, these systems risk reinforcing existing gender inequalities and creating new forms of psychological risk, such as stress, anxiety and burnout as a result of reduced autonomy and impersonal task allocation. When algorithms also determine pay and dismissal decisions, job insecurity is further exacerbated. In addition, reduced human interaction and reliance on standardised performance evaluations can lead to social isolation and restrict opportunities for career progression, particularly for women in male-dominated roles. As De Stefano and Aloisi (2022) note, when combined with the potential for algorithmic bias to produce unfair or discriminatory outcomes, these factors can significantly undermine both employees' well-being and their professional prospects.

Over the past decade, algorithmic management systems have been studied primarily in the context of platform work, including both on-location digital platforms and online digital labour platforms. Research increasingly shows that these systems profoundly affect labour conditions and worker well-being, largely through the intensification of work (EC 2023; Matilla-Santander et al. 2025).

In certain kinds of online platform work, such as content moderation, workers face severe psychological risks as

they are routinely exposed to violent, abusive or illegal material. This can lead to long-term harm, including anxiety, insomnia and symptoms of post-traumatic stress. Algorithmic management exacerbates such stress, as reviewers must meet strict quotas within limited timeframes and maintain high reputation scores to secure future tasks. Together, these pressures create a highly stressful work environment that undermines both mental well-being and a sense of control (Lenaerts et al. 2022).

Similarly, on-location platform workers experience significant impacts on their physical, mental and social well-being. Algorithmic systems monitor and direct their work, pushing for faster performance and intensifying workloads. Isolation from colleagues, coupled with customer satisfaction rating systems, increases stress and diminishes opportunities for peer support. The opacity of decision-making, constant surveillance and unpredictability of algorithms further exacerbate insecurity and erode autonomy.

Although gender has received comparatively limited research attention, emerging evidence suggests that female platform workers face distinct vulnerabilities under algorithmic oversight. This not only reproduces existing labour market inequalities but also intensifies them, highlighting the urgent need for a more systematic and gender-sensitive analysis of its consequences. Vignola et al. (2023) emphasise the importance of examining gender disparities in this context, arguing that the intersection of algorithmic management with precarious employment structures amplifies risks for women workers and requires more targeted research and intervention.

This dynamic is particularly visible in the care sector, in which platform labour models have been expanding rapidly. Care work, which is historically undervalued and largely informal, has been profoundly reshaped by digital platforms, which have exploited its existing fragility. These platforms depend heavily on migrant women from the Global South, whose restricted access to alternative employment opportunities renders them highly susceptible to exploitation. Inequalities of gender, race and immigration status are mobilised systematically to secure a compliant and low-cost workforce. Although platform providers often present themselves as enabling access to flexible employment, in practice they entrench the precariousness of female migrant workers (Rodríguez-Modroño et al. 2022).

To summarise, there is a growing need to examine more closely – paying particular attention to women's experiences – how automation technologies create new psychosocial risks and exacerbate existing ones. In the context of robotics, psychosocial hazards often stem not only from the technology itself but from managerial decisions, work design and limited worker involvement in the implementation and customisation of systems, which can have both short- and long-term consequences. Similarly, with data-driven technologies, it is essential to consider the social and ethical dimensions of their design and deployment. Gender bias can be embedded in both datasets and algorithms, reproducing existing inequalities, while algorithmic management can expose female workers to distinctive vulnerabilities under oversight. Further research is needed to deepen our understanding of these dynamics and to inform the development of effective, gender-sensitive OSH policies. These are essential for addressing the evolving and potentially intensifying risks associated with automation technologies in the workplace.

4. Older workers

The fourth and final theme identified in the scoping review focuses on ageing workers, highlighting the fundamental economic shifts resulting from Europe's ageing population. At present, there is no comprehensive framework for interventions that addresses the dual challenge of an ageing workforce and rapid technological change. This leaves older workers caught between policies promoting extended working lives and the persistent ageism and pressures toward early retirement that they encounter in the labour market (Alcove et al. 2021).

While this paper has already emphasised the importance of career trajectories – not only entering but also remaining in STEM and research-intensive fields – particular attention must be paid to workers who are already active in the labour market, but may face career transitions later in life. This is becoming even more important in light of projections that by 2030 workers aged 55–64 will account for 55 percent of the total labour force in most European countries, with older women representing the fastest-growing segment (Berson and Botelho 2023).

When discussing labour market outcomes, it is clear that older people already face a variety of challenges in accessing employment and employer-funded training. Although the past two decades have seen a steady increase in the employment of people aged 55–64, many mature workers continue to encounter discrimination and negative stereotyping. Employers often perceive them as less capable, less productive, less adaptable and less innovative than their younger peers. Consequently, mature workers are more likely than any other age group to experience long-term unemployment when they lose their jobs. Even when mature workers succeed in re-entering the labour market through training programmes, they are often placed in lower-paid, less secure positions than their younger counterparts (Schmidpeter and Winter-Ebmer 2021).

One explanation for the obstacles older workers face is the relationship between age and productivity, which often follows an inverted U-shape, typically peaking around the mid-50s. This relationship is influenced by

multiple factors, and many companies are hesitant to hire older workers due in part to seniority-based wage structures, especially in countries with strict employment protection rules. In these settings, wages tend to rise with job tenure, creating a gap between the labour costs related to long-serving older employees and their productivity. Such imbalances can discourage employers from recruiting older candidates if they expect to command comparable wages (EC 2024a).

Beyond purely economic explanations, maintaining work capacity depends not only on the efforts of the individual but also on the conditions and support provided by the work environment. Factors such as workplace design, organisational culture, access to training and managerial practices can all shape an older worker's ability to sustain performance and adapt to changing demands. These influences often affect men and women differently as a result of gendered expectations, roles and opportunities in the workplace (Alcove et al. 2021). Aisa et al. (2023) argue that the perceptions and attitudes of both workers and employers play a crucial role in shaping training and development opportunities. Managers often hesitate to invest in employees approaching retirement, perceiving them as less adaptable to change. At the same time, older workers may be less motivated to adopt new technologies, which are frequently regarded as difficult to use. Persistent stereotypes suggesting that older employees are less willing to engage in self-development can further reduce interest in training, affecting both firms' willingness to offer it and workers' willingness to participate.

Based on the Digital Economy and Society Index 2022, only 54 per cent of Europeans aged 16–74 possess at least basic digital skills (the proportion among older adults is significantly lower). In 2023, only 28 per cent of EU citizens aged 65+ had basic digital skills (Eurostat 2024). As technological complexity continues to evolve, however, they can further widen the age-related knowledge gap, leaving older workers increasingly insecure in the labour market. In addition, the integration of robotics and data-intensive technologies might exacerbate this vulnerability, creating new occupational safety and health risks for all workers, including older ones, as discussed in the previous chapter.

Moreover, Albinowski and Lewandowski (2024), analysing the gender- and age-specific dimensions of the impact of new technologies on European labour markets, find that the age- and gender-specific effects of technology adoption drive the different effects of robot and ICT exposure on younger and older workers and on men and women, rather than the occupational composition of the jobs held by various demographic groups. In particular, women aged 60 or older are the group most negatively affected by technology adoption in Europe. As negative labour market effects such as unemployment, job displacement or reduced opportunities often push older workers toward early retirement, these dynamics highlight the broader risks of technological change for sustaining longer and more stable careers. Casas and Román (2023) examine its implications for early retirement decisions across 26 European countries. Their analysis draws on microdata from the Survey of Health, Ageing and Retirement in Europe, combined with occupation-level measures of automation degree and risk, as well as a technological classification of occupations. The findings indicate that technological change significantly influences early retirement decisions. More specifically, it affects men and women differently, contributing to a widening gender gap: women's working lives are being shortened more rapidly than men's, suggesting that technological change may be disproportionately pushing women out of the labour market and exacerbating overall gender inequalities.

As a result, women's earlier and more frequent exits from the labour market translate into shorter contribution periods and thus lower pension entitlements, thereby widening the pension gap and heightening their risk of poverty in old age. According to Eurostat (2021), women in the EU aged 65 and over received pensions that were on average 29 per cent lower than those of men. This gender pension gap is rooted in structural inequalities throughout women's working lives. Factors such as the gender pay gap, earlier retirement ages and career interruptions related to caregiving not only shape women's employment trajectories but also reduce their pension entitlements. Consequently, women are more likely to depend on state pensions in old age, but less likely to qualify for the full amount.

Such gender disparities in pension entitlements reflect and contribute to the broader issue of income insecurity among older people in the EU. Despite ongoing discussions on increasing the retirement age across many EU countries as a response to ageing populations and pressures on pension systems, evidence shows that the risk of poverty and social exclusion among older people has continued to grow over the past decade. This increase has been driven largely by rising relative income poverty, even as material and social deprivation has declined. In 2022, more than one in five people aged 65 and over in the EU – around 18.5 million people – were at risk of poverty or social exclusion, a figure that continues to rise due both to population ageing and higher poverty rates (EC 2024b). Although national contexts differ considerably, women consistently face higher poverty risks than men in every EU country. Advanced old age further amplifies this vulnerability: in 2022, almost one in four women aged 75 and above were at risk of poverty or social exclusion (EC 2024b).

Evidence from Germany further illustrates how these challenges are projected to intensify: assuming stable employment and interest rates, the risk of old-age poverty is expected to rise significantly over the next two

decades. By 2036, around 20 per cent of pensioners aged 67 are projected to be affected. The groups most at risk include single women, the long-term unemployed and low-skilled workers. The outlook is particularly concerning for single women, with nearly one in three expected to require basic social security benefits in retirement. Between 2015 and 2036, the proportion of female pensioners entitled to such benefits is projected to increase from 16 to almost 28 per cent, resulting in a risk of old-age poverty for single women that is nearly four times higher than the average rate of 7 per cent (ZEW 2017). This evidence points to a widening gender gap in economic security in old age, emphasising the importance of addressing structural inequalities in both the labour market and pension systems.

Despite these concerning projections, later-life employment patterns are not uniformly negative; new trends such as so-called »un-retirement« offer a more nuanced picture. Many older adults continue to face financial insecurity, declining health and uncertainty about the future, but research also points to un-retirement as a growing phenomenon in which individuals re-enter the labour market following retirement. Beyond financial considerations, many report a sense of loss upon leaving work. A survey by Randstad found that 32 per cent of retirees felt they needed employment in their lives. Work provides more than income; it also offers meaning, purpose, social interaction and mental stimulation, helping individuals remain engaged and fostering a continued sense of belonging (Randstad 2023). Research further suggests that returning to work is not driven solely by financial necessity; for many, un-retirement represents a lifestyle choice that provides continued engagement and purpose (Lassen and Vrangbæk 2021). This decision is also influenced by the nature of retirees' skills: those whose skills are less vulnerable to automation are particularly likely to find the prospect of returning to work appealing, and the relationship between skill automatability and un-retirement remains significant even after accounting for psychological and financial circumstances (Lee 2022). These findings highlight that later-life employment is shaped by financial, social, and technological factors, and that retirees' skills and vulnerability to automation should direct labour market policies that sustain meaningful engagement among older workers.

Overall, this section illustrates how ageing, gender, and technological change might shape more negative labour-market outcomes and undermine pension security for older workers. Persistent disparities and ageism—including limited opportunities for retraining and the prevalence of early retirement, particularly among women—may pose significant challenges as emerging technologies continue to transform work. At present, only a small number of studies address these issues, highlighting the need for further research to better understand the mechanisms driving these disparities, especially as European societies continue to age in parallel with ongoing digital transformation. Such insights will be essential for designing policies that support more inclusive labour-market transitions for older adults.

Conclusion

Drawing on peer-reviewed research, policy reports and grey literature, this scoping review has mapped current research trends and highlighted conceptual and empirical gaps that limit our understanding of how technological change reshapes women's working lives. The review situates automation within the broader socio-economic transformation, highlighting the intersections between the integration of new technologies in the workplace and existing gender divisions within labour markets.

The emerging evidence suggests that automation may pose specific challenges for women's employment trajectories, potentially widening wage and employment gaps in the absence of targeted policy interventions. The introduction of new technologies brings new psychosocial risks affecting worker's well-being, from uncertainty about the future of employment and loss of autonomy to increasing stress and job strains. In the context of ageing populations and extended working lives, women may face career changes later in life, and ageism in the labour market can increase the likelihood of early retirement, ultimately contributing to lower lifetime pension accumulation and a heightened risk of social exclusion in older age. Together, these dynamics highlight the urgency for introducing gender-responsive policies that address both immediate workplace risks and longer-term vulnerabilities across the life course.

Adaptability to automation is frequently framed in individualised terms, focusing on workers' skills and resilience while neglecting structural determinants such as precarious work, deregulation and the erosion of employment security. These processes reveal that adaptability is unequally distributed and shaped by institutional and social contexts. Institutional factors – such as welfare regimes, care systems and models of industrial relations – play a central role in shaping gendered outcomes and must be incorporated into future analyses. Moreover, the limited application of intersectional perspectives obscures how automation intersects with other forms of inequality, including class, age and migration status. Addressing these gaps is essential not only for developing effective policy measures to promote gender equality in evolving work environments but also for advancing scientific understanding of the interplay between social structures and digital transformation, rather than treating them as separate domains.

Despite ongoing public discussion of women entering STEM fields, current research tends to overlook female-dominated sectors such as health care, education and

services. This limits its analytical depth and policy relevance. Efforts to promote women's STEM participation must go beyond recruitment to encompass retention, leadership development and organisational measures that address structural bias. Similarly, studies on the gender wage gap remain disproportionately focused on manufacturing, examining industrial robots while giving limited attention to AI and robotics in female-dominated fields. Future research should prioritise institutional and contextual factors – including structural barriers, workplace culture and organisational norms – that shape the gendered effects of technological change on employment and wages.

Beyond structural and occupational inequalities, automation also introduces psychosocial risks for both women and men that require careful attention and gender-sensitive occupational safety and health (OSH) measures. The risks associated with robotics and data-intensive technologies arise not only from organisational practices and work design but also from the limited involvement of workers in decision-making, rather than from the technologies themselves. Collectively, these factors and practices can undermine mental health, autonomy and overall job satisfaction.

Finally, although extending working lives is often framed as a pragmatic response to demographic pressures, its implementation in technologically evolving workplaces presents significant challenges. Structural barriers – including age discrimination, limited access to retraining and pressures for early retirement – continue to undermine inclusive employment strategies. These challenges are highly gendered, reflecting accumulated disadvantages over the life course that constrain older women's opportunities for meaningful participation. Addressing them requires age- and gender-responsive policies that promote flexible work arrangements, lifelong learning and robust anti-discrimination measures. Further research is needed on the intersection of ageing, gender and technological change to ensure that policies aimed at extending working lives promote inclusive participation in the labour market, rather than reinforcing and increasing existing inequalities.

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About the Author

Dr Inga Sabanova is a Policy Officer at the FES Competence Centre on the Future of Work, where she has been managing a portfolio of projects examining how emerging workplace technologies are shaping the future of work, and how inequalities related to gender, migration, age and social class persist and evolve in a technologically driven workplace.

Her projects include:

- → Artificial Intelligence and Gender Equality, including organising the policy conference Towards Gender-Inclusive Digital Policy: AI and Gender Equality in the Workplace in Brussels (2025).
- → PhD Summer Schools, held in 2022, 2023, and 2024.
- → Mapping the Platform Economy, including the report Online Platforms and Platform Work: The Complex European Landscape (2022).

Changing Working Lives: Women and Automation in the Labour Market

This paper takes a policy-oriented approach. It draws on evidence from peer-reviewed research, policy reports and 'grey literature' to examine the potential impact of automation on women's participation in the labour market. This important topic has largely been overlooked in current policy debates. The paper analyses how the existing literature address the impact of automation, particularly at the intersection of gender and labour market dynamics, and in relation to structural and systemic barriers that sustain gender disparities. It also identifies emerging themes that policymakers should prioritise when considering the gendered dimensions of automation and their implications for the future of work.

Based on a scoping review, the paper maps current research trends and highlights key limitations that require further attention from academic researchers. This will enhance our understanding of changing working conditions and inform policymaking. It focuses on four critical themes: workers' adaptability within the framework of workplace automation; gender employment and wage gaps in relation to technological change; the relationship between automation technologies and occupational safety and health, with particular attention to how women may be subject to new risks; and the implications for an ageing workforce in the context of technological change.

Further information on the topic can be found here:
↗ **fes.de**

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