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ORIGINAL ARTICLE

Automation and segmentation: Downgrading employment quality among the former “insiders” of Western European labour markets

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Abstract

The literature on labour market segmentation traditionally looks at servitisation as the main structural driver behind the rise of employment precariousness, overlooking another crucial engine of the knowledge-economy transition: the Information and Communication Technologies (ICT) revolution. This paper proposes a task-based approach to complement the skill-biased framework usually applied to labour market segmentation, investigating the correlation between occupational exposure to the risk of automation and low-quality employment. The empirical analysis, based on 14 countries sampled from ESS (2002–2018), shows a strong correlation between technological replaceability and low income across all of Western Europe, especially after the Great Recession, while its association with atypical employment is mainly driven by fixed-term contracts in Central and Southern Europe and by part-time arrangements in Anglo-Saxon and Scandinavian countries. Overall, a “recalibrated” dualisation emerges in Western European labour markets, characterised by the diffusion of low labour earnings and atypical contracts among mid-skill routine workers, besides the low-skill service precariat.

KEYWORDS

atypical employment, automation, dualisation, labour markets, low income, political economy, segmentation, tasks

INTRODUCTION

In the last four decades, the transition of Western economies toward knowledge-based growth models has been accompanied by rising income inequalities and economic insecurity (Hall, 2022). These phenomena are often traced back to the increasing segmentation of the labour markets that followed the expansion of service production, prompting the rise of low-paid and atypical

employment particularly among low-skill service workers (Häusermann & Schwander, 2012; Oesch, 2006). However, empirical research shows that low-quality jobs have been spreading across the workforce and the educational ladder (Eichhorst & Tobsch, 2015; Häusermann et al., 2015; Schwander & Häusermann, 2013; Seo, 2021). In this regard, an inquiry into the impact of automation on the working conditions of middle-skill workers is expected to improve our understanding of labour market

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segmentation in the knowledge economy. Although predictions of mass displacement of clerical and blue-collar jobs have been downsized, particularly with regard to Europe (Fernández-Macías & Hurley, 2017; Oesch & Piccitto, 2019), few empirical contributions have examined whether task routineness accounts for the diffusion of low-quality employment among these former “insiders” of the Fordist labour markets (Kurer & Palier, 2019; Küstermann, 2022; Parolin, 2020).

This paper aims to bridge this gap in the literature, testing whether the threat of technological replaceability in the workplace positively correlates with atypical employment and low income in Western Europe. Delving deeper into the mechanism, I posit an indirect relation between automation risk and low income, significantly mediated by the expected rise of atypical forms of employment among mid-skill workers. The precarisation of at-risk occupations is expected to encounter significant longitudinal and cross-sectional variations. I expect the positive associations between automation risk and precarious employment to become stronger after the Great Recession of 2007–2009, as a result of the amplifying effect of economic downturns on job automation (Jaimovich & Siu, 2012). Concerning the moulding effect of political-economic institutions, I expect the correlation between automation risk and low income not to be significant in Scandinavian countries, thanks to their universal wage bargaining system, while the effect on atypical employment should not be significant in Central Europe, where labour protection for mid-skill workers has been preserved.

To test this set of hypotheses, I rely on the first 9 waves of the European Social Survey (2002–2018), sampling 14 advanced market economies that belong to different political-economic institutional setups (AT, BE, DE, DK, ES, FI, FR, GB, GR, IE, IT, NL, PT, SE). Using mainly Ordinary Least Squares (OLS) multivariate models, complemented by several robustness checks, I find that the exposure to automation risk is positively correlated with low-income, fixed-term employment and perceived income insecurity, while not being significantly correlated with part-time contracts. Structural equation models show that only a small portion of the effect¹ of automation risk on low income is conveyed through atypical employment. Although I am not able to test the possible mediating role of wage dynamics, descriptive evidence based on the macro data from the Structure of Earnings Survey (SES-Eurostat, 2002–2018) provides tentative support for that indirect relation, showing a stark divergence between the rising labour earnings of

high-skill professions and the stagnating wages of both mid- and low-skill occupations. The Great Depression appears to have decisively worsened the effect of automation on low income. Finally, against expectations, the relation between technological replaceability and low income does not show significant cross-country variation, whereas two patterns of precarisation emerge in Western Europe with regard to atypical contracts: automation risk is significantly associated with fixed-term contracts in Central and (more weakly) Southern Europe, while being correlated with part-time contracts in Anglo-Saxon and Nordic countries.

This work contributes to a broader understanding of labour market segmentation, enriching the literature on this topic with the task-based analytical lens adopted by automation scholars. The empirical evidence shows that mid-skill routine workers are experiencing labour precariousness, particularly in the form of (objective and perceived) low income. Therefore, a “recalibrated” dualisation of the European labour markets seems to emerge, characterised by the diffusion of low labour earnings and atypical contracts among both the low-skill service precariat and mid-skill routine workers. The precarisation of typical middle-class occupations, once tied to opportunities for societal upward mobility and generous social protection (Esping-Andersen, 1990; Iversen & Soskice, 2019), may reasonably account for the growing discontent of these workers voiced through the support for the radical right (Anelli et al., 2019; Kurer & Palier, 2019).

The paper is structured as follows. The next two sections review the literature on labour market segmentation and the impact of automation on the labour market. In the fourth section, I posit a relation between task routineness and downgrading labour quality. Empirical strategy and findings are presented in the following two sections. In the last section, I discuss the results, limitations and broader implications of this analysis.

SEGMENTATION OF WESTERN LABOUR MARKETS AND VARIETIES OF PRECARIOUSNESS

Over the past four decades, Western labour markets have gone through relevant structural transformations, departing from the “industrial equilibrium.” The political-economic setup that ruled between the end of WW2 and the 1980s is usually labelled as the “golden age” of capitalism, characterised by (nearly) full male employment—primarily led by industrial development—welfare state expansion and a general reduction of socio-economic inequalities (Häusermann & Schwander, 2012). The

¹I use the term “effect” for the sake of simplicity, although it refers to correlational associations (non-causal research).

literature points out three intertwined processes of socio-economic changes that shook this equilibrium, resulting in the emergence of work precariousness, that is, a state in which an individual cannot gain sufficient resources either from participating in the labour market or from social benefits (Berton et al., 2012). Above all, an unprecedented rise of low-paid jobs has been associated with the tertiarisation of advanced economies, which scholars generally lead back to the lower potential of services' productivity compared to the manufacturing sector (Iversen & Wren, 1998). The expansion of university education further contributed to the process of labour market precarisation, particularly fostering an economic polarisation between high-skill and low-skill service jobs. This outcome is generally traced back to stronger market demand for highly educated workers who, in addition, present higher productivity and resistance to substitutability (Card & Lemieux, 2001; Katz & Murphy, 1992). Lastly, employment feminisation is presented both as a driver and a consequence of the two processes just mentioned (Häusermann & Schwander, 2012).

Following these transformations, the post-industrial labour market shows a more uneven and variegated distribution of working conditions among the labour force. Departing from neo-classical theories, economic and sociological literature has been interpreting this heterogeneity as the result of a structural segmentation of the labour market along different institutional and societal barriers that prevent a fairer allocation of jobs and wages across the workforce (Doeringer & Piore, 1971; Reich et al., 1973).² Within the tradition of segmentation studies, the dualisation theory has become the reference framework, resuming labour market fragmentation in two large groups, characterised by different forms of employment. The focus on labour formal arrangements is motivated by the unprecedented flexibilisation of labour market institutions, which has accompanied the service transition—both as a determinant (Fernández-Macías, 2012) and a consequence (Thelen, 2014)—enhancing the creation of non-standard (or atypical) employment. Consequently, a cleavage has emerged between the so-called “insiders” of the labour market, provided with open-ended and full-time contracts and the “outsiders,” trapped in temporary and part-time jobs (Rueda, 2005). The second group is largely composed of low-skill service workers (e.g., sales workers, caregivers, janitors, waiters, etc.) (Häusermann & Schwander, 2009), characterised by low earnings, little chances of upward

mobility and—as a result of fragmented careers—poor social protection (through insurance schemes) (Häusermann & Schwander, 2012).

However, the heuristic exhaustiveness of dualisation theory as a framework to investigate employment precariousness has been increasingly questioned. The struggle to ensure sufficient resources through labour market participation—as suggested by the concerning growth of in-work poor³ (Barbieri et al., 2018; Lohmann & Marx, 2018)—is experienced across the labour market, increasingly more among the segment provided with standard employment, transcending the insider–outsider divide (Eichhorst & Tobsch, 2015; Jessoula et al., 2010; Seo, 2021). Hence, a specific focus on low-income employment is needed to better grasp the rise of work precariousness.

All in all, following the post-industrial transition, Western labour markets have shifted from a homogenous and stable allocation of jobs and wages for the entire (male) workforce toward a segmented configuration, which traps groups of workers in atypical and low-earning jobs. The sectoral and educational changes associated with the service transition are usually summoned as the structural drivers of segmentation, but the reference to other coeval processes of economic transformation might enrich the understanding of this phenomenon. Particularly, a wider perspective based on the transition toward the knowledge economy encourages focusing on the possible role played by automation in the rise of work precariousness, suggesting occupational tasks as an understudied principle of segmentation.

THE PUZZLING IMPACT OF AUTOMATION ON THE LABOUR MARKET: ARE MID-SKILL WORKERS THE REAL LOSERS?

The rise of service employment and the related educational revolution are often used by segmentation scholars as the explanatory background of increasing work precariousness. Such a narrow focus prevents a broader assessment of the effects associated with the overarching political-economic shift toward knowledge-based growth models faced by Western countries (Hall, 2022). Technological change, particularly the growing relevance of

²Various sources of labor market cleavages have been used to explain economic segmentation, including firms' size (Doeringer & Piore, 1971), geographical differences (Hanson & Pratt, 1992; Peck, 1996), ethnicity (Wang, 2010), and gender (Peetz & Murray, 2017).

³Eurostat shows that in-work poor—defined as the individuals employed for at least 7 months in the reference year whose household's income scores below the 60% of the median national income (Barbieri et al., 2018; Lohmann & Marx, 2018)—were almost 12% of the European workforce in 2019. Data available at https://ec.europa.eu/eurostat/databrowser/view/ILC_IW01/default/table?lang=en.

Information and Communication Technologies (ICT) in the labour market, is a crucial component of this transformation (Diessner et al., 2025; Powell & Snellman, 2004)—analytically distinct from servitisation (Wren, 2013)—which tends to be overlooked in the segmentation scholarship.

A prolific stream of labour economics literature has been investigating the occupational consequences of automation, mainly focusing on the potential for substitution of human labour famously predicted by Keynes ([1930] 2010). Scholars first argued that information technologies, in line with the effect of tertiary education's expansion, were to raise the demand for highly educated workers at the expense of the low-educated ones (i.e., “skill-biased technical change” [SBTC]) (Manning, 2004). This model has been challenged by new evidence brought by Autor et al. (2003), which shows a steep decline in the share of mid-skill occupations since the ICT advent. The proponents of the new framework, called “routine-biased technical change” (RBTC), argue that the high routine-task intensity of these occupations—mainly manual-industrial and clerical jobs (e.g., skilled metalworkers, bank tellers, office secretaries, etc.)—is at the origin of their fall, being easily codifiable and replaceable by machines (Autor, 2015). On the contrary, both low- and high-skill occupations act as a complement of technology in the labour market, performing non-automatable tasks that involve creativity, adaptability and in-person relations.

However, recent contributions show that the distributional impact of automation on mid-skill workers is not as disruptive as RBTC initially predicted. While the literature shows a robust association between replacement risk and wage reduction (Braxton & Taska, 2023; Parolin, 2020), the large majority of at-risk workers appear to retain their jobs (Kurer & Gallego, 2019). On the contrary, upgrading trends in the allocation of job opportunities and wages emerge in Western European labour markets (Fernández-Macías & Hurley, 2017; Oesch & Piccitto, 2019; Tåhlin, 2007), with significant cross-country heterogeneity associated with the capabilities of political-economic institutions to enhance or moderate the demand for low-skill service jobs (Fernández-Macías, 2012; Oesch & Rodríguez Menes, 2011). The latter is further influenced by the entrance of women and migrants from low-income countries into the workforce, that longstanding discrimination forces in the low-skill segment of the labour market regardless of their educational level (Andersson et al., 2019; Borjas & Monras, 2017; de Muñoz Bustillo & Anton, 2012; Dwyer, 2013; Grimshaw & Figueiredo, 2012; Magnusson & Tåhlin, 2023; Oesch, 2013).

The residual decline of mid-skill occupations at the aggregate level can be mainly attributed to a gradual intergenerational phase-out with fewer new entries than retirees in that segment of the workforce (Cortes, 2015; Kurer & Gallego, 2019), as the coexistence of routine and non-routine tasks in most occupations prevents a large-scale replacement of human labour (Fernández-Macías & Bisello, 2016). In lieu of substitution, recent studies have been emphasising technology-led reorganisation of labour processes and tasks, particularly with the introduction of machine learning algorithms (Brynjolfsson et al., 2018; Frey & Osborne, 2017), possibly resulting in increased standardisation of previously non-routine tasks (Fernández-Macías et al., 2023). Furthermore, the literature shows that mid-skill replaceable workers experience wage reduction, limited career advancement opportunities and reallocation to lower-skill tasks (Autor, 2013; Küstermann, 2022). More broadly, there is growing evidence of increasing diffusion of low-income and atypical employment across the workforce and the educational ladder (Eichhorst & Tobsch, 2015; Häusermann et al., 2015; Schwander & Häusermann, 2013; Seo, 2021). Confirmation of growing socioeconomic insecurity among mid-skill workers is also found at the perceptual level, as behavioural studies show a strong association between occupational routineness and a decline in subjective societal status and prestige, often linked with rising support for radical right parties (Anelli et al., 2019; Hughes et al., 2024; Kurer, 2020). This evidence suggests further investigation of the role of task routineness in shaping workers' labour conditions, prompting a focus on employment quality rather than quantity.

AUTOMATION AND LABOUR PRECARIOUSNESS IN WESTERN EUROPE: TASKS AS A POSSIBLE NEW SOURCE OF WORKFORCE SEGMENTATION

A wide literature has been exploring the influence of occupational features on job quality, although the analytical lens of these studies has usually been centred on skill requirements, showing a positive correlation between skill complexity and better working conditions in line with SBTC (Oesch, 2013; Oesch & Piccitto, 2019; Tåhlin, 2023). However, the ICT revolution may entail an additional barrier to better job opportunities for workers whose tasks, which require an intermediate level of education, have become less valuable in the labour market due to machines' capability to execute them. Only a few empirical contributions have inquired into the role played by occupational routineness in downgrading job

quality, mainly focusing on wages and life satisfaction (Braxton & Taska, 2023; Fernández-Macías, 2012; Fernández-Macías & Hurley, 2017; Küstermann, 2022; Parolin, 2020).

Extant literature lacks a more encompassing empirical investigation on labour precariousness, especially with regard to the possible correlation between task repetitiveness and atypical employment (only tested, to my knowledge, at the aggregate level by van Doorn & van Vliet, 2024). Although the shrunk prominence of routine occupations in the production system does not result in mass unemployment, it is expected to significantly affect the access of mid-skill workers to rising wages and stable jobs. The repetitiveness of their working tasks, be they entirely manual or cognitive, excludes these workers from the benefits of increased knowledge tradability and rents, reserved for high-skill creative occupations only (Antonelli & Tubiana, 2020, 2023). In that regard, the additional technology-based source of labour market segmentation suggests updating the SBTC framework, as mid-skill routine workers are expected to encounter similar low-quality employment conditions to non-routine manual workers. More precisely, task routineness inherent to clerical and blue-collar occupations is posited to be associated with atypical employment and low levels of income (relative to high-skill occupational groups). In line with the dualisation theory, I also expect the rise of atypical employment among automation “losers” to significantly contribute to the increase of low income in this segment of the workforce, constituting an indirect relation.

H1. The exposure to automation risk is positively correlated with low-income and atypical employment.

H2. The positive effect of automation risk on low income is mediated by atypical employment.

The posited relations are expected to show both significant longitudinal and cross-sectional variations. Concerning the longitudinal change, the literature shows a stark acceleration in the pace of job automation during economic downturns. In the last four decades, most of the employment losses in routine occupations occurred amidst financial crises, especially during the Great Recession of 2007–2009, showing no sign of recovery afterwards (Autor & Dorn, 2013; Jaimovich & Siu, 2012). In addition to job replacement, economic downturns can be reasonably expected to worsen the employment conditions of routine workers, enabling the diffusion of precarious forms of employment across the workforce. The

main mechanism lies behind the increased pressure for cost reduction on enterprises, which prompts workers to accept downgraded (or stagnating) employment conditions in exchange for job retention (Erhel et al., 2022; Piasna, 2017). A crucial institutional enabler of the precarisation of former “insiders” jobs, particularly with regard to the diffusion of atypical employment, is the generalized flexibilization of employment protection legislation and wage bargaining systems undertaken by governments of advanced market economies under the austerity dogma (Leschke, 2012; Pavolini et al., 2015; Picot & Tassinari, 2017; Ray & Schwander, 2020; Sacchi, 2015). Therefore, I expect the automation “losers” to shift more markedly toward low-income and atypical employment in the aftermath of the last major financial crisis.

H3. The positive effect of automation risk on low-income and atypical employment significantly increased after the Great Recession (2007–2009).

The crucial intervening role of political-economic institutions in labour automation is also expected to be associated with significant cross-sectional heterogeneity. The former is to be conceived as a process endogenous to the structural and institutional context, which shapes its unfolding from technologies’ development to their adoption in workplaces and their following occupational impacts (Fernández-Macías & Hurley, 2017; Mazzucato, 2013; Oesch & Rodriguez Menes, 2011; Van Reenen, 2011). Building on that literature, I expect to observe great variation in the precarisation of automation “losers” among the clusters traditionally proposed by comparative political economists to classify European countries (i.e., Bismarckian/Central European, Social Democratic/Scandinavian, Liberal/Anglo-Saxon and Southern). Although a detailed analytical reconstruction of the political-economic mechanisms affecting the precarisation of routine occupations is beyond the scope of this paper, I build a hypothesis on the descriptive cross-cluster variation presented in the literature. I expect the positive correlation between technological replaceability and atypical employment to be weaker in Central Europe, where labour protection for mid-skill workers (particularly in the manufacturing core) was preserved during the post-industrial transition (Palier & Thelen, 2010). On the contrary, the generalised labour market deregulation deployed in Anglo-Saxon and Southern European countries, as well as the embedded flexibilisation characterising the Scandinavian cluster, are expected to have enhanced the diffusion of atypical employment in that once-secure segment (Ferragina & Filetti, 2022;

Pavolini et al., 2015; Picot & Tassinari, 2017; Thelen, 2014). Concerning low income, I expect a strong correlation with automation risk in the deregulated Anglo-Saxon and Southern labour markets, but also in Central Europe, where low-earnings jobs have been transcending the insider-outsider boundaries (Eichhorst & Tobsch, 2015; Seo, 2021). Better protection against such a risk should be granted by the Scandinavian encompassing bargaining system, which prevents wage dispersion (Thelen, 2014).

H4a. The positive effect of automation risk on low income is significant in all clusters except for the Scandinavian countries.

H4b. The positive effect of automation risk on atypical employment is significant in all clusters except for the Central European countries.

DATA AND EMPIRICAL STRATEGY

I rely on multivariate OLS models⁴ to test the correlation of individual exposure to technological replaceability, operationalised at the occupational level, with low-income (objective and perceived), fixed-term and part-time employment. In addition, I use generalised structural equation models to test the mediating effect of atypical employment in the relation between automation risk and low income. The analysis is run on the first nine waves of the European Social Survey (ESS), covering the timeframe 2002–2018. ESS was preferred to other surveys as it includes both objective and subjective variables of socio-economic conditions, the second one deemed crucial to better capture the phenomenon of labour precariousness (Häusermann & Schwander, 2009; Seo, 2021). Furthermore, this survey combines an encompassing country selection with a wide time coverage. I rely on a sample of 14 advanced market economies that experienced a significant—although varied—shift toward knowledge-based growth around the turn of the century (AT, BE, DE, DK, ES, FI, FR, GB, GR, IE, IT, NL, PT, SE), ensuring variation of political-economic institutional settings and economic performance in the last two decades.^{5,6}

⁴Each model is adjusted for the “analysis weight” as recommended by ESS: https://www.europeansocialsurvey.org/docs/methodology/ESS_weighting_data_1_1.pdf.

⁵The case selection is oriented toward knowledge-intensive market economies, which are more likely to encounter an advanced deployment of ICT in the labor market. Central-Eastern European countries are not included in the sample since their growth models heavily rely on FDI-led manufacturing production (Bohle & Greskovits, 2012).

Independent variable: The Routine Task Index

I use the so-called “Routine Task Index” (RTI) as a proxy of individual exposure to the risk of technological replacement in the labour market. RTI is a widely used measurement in the literature on the occupational consequences of automation (Autor et al., 2003), and it captures the degree of routine of each occupation based on its working tasks. This index is calculated on the American O*Net database, using the formula of Acemoglu and Autor (2011),⁷ and it is coded at three-digit ISCO88 and ISCO08 to match the classification used in each ESS wave.⁸ Each survey respondent is assigned a standardised RTI score based on her/his current occupation. A graphical representation of the RTI distribution across occupational groups is presented in Figure A1.1.

Dependent variables: Low-income and atypical employment

I use four binary survey variables to capture workers with low-income and atypical employment. Low income is operationalised by a binary variable, restricted only to respondents (aged 18–59) currently not unemployed, taking a value one when the individual's household income lies in the first three deciles of the income distribution.⁹ Since the literature suggests including subjective measurements of income insecurity for a better understanding of labour segmentation (Häusermann & Schwander, 2009; Seo, 2021), I supplement the operationalisation of low income with a binary variable measuring perceived difficulties of employed individuals in coping with present income. Lastly, I operationalise atypical employment with two binary variables, restricted to individuals currently not unemployed, identifying fixed-term contracts (opposed to open-ended) and part-timers (below 30 working hours in a week).

Intervening variables

The cross-sectional variation of the main relations is explored through split-sample models and multiplicative

⁶Around 137,000 observations are included in the models run on fixed-term contracts, 163,000 when analyzing part-time employment, and 92,000 in the models run on low income (objective and perceived).

⁷I thank Dario Guarascio and Roberto Quaranta for sharing the data on RTI.

⁸ISCO88-ISCO08 correspondence table from Weksler and Lastra (2022).

⁹This item resembles the standard definition of in-work poverty (Lohmann & Marx, 2018), although the lack of absolute figures on income in the ESS precludes capturing the same object.

interactions. I run the regression models separately for each cluster of European political economies¹⁰ to test the influence of the institutional context on the precarisation of the automation “losers.” I run additional exploratory analyses on the moderating effect of political-economic institutions testing the interactions of task routineness with national levels of trade union density and the generosity of assistance-based public transfers (Nelson et al., 2020).¹¹ Finally, I explore the longitudinal variation of the automation's effect on work precariousness throughout all the ESS editions using multiplicative interactions to test the accelerating effect of the Great Recession.

Control variables and robustness checks

Testing the effect of automation risk taken in isolation from other intertwined sources of occupational threat may lead to wrong estimations. Particularly, the interaction between the ICT revolution and economic globalisation is associated with the emergence of another potential labour market risk that is worth taking into account. The possibility of remote service provision through ICT devices exposed mid- and high-skill service occupations, which do not require in-person interactions, to competition with foreign providers (Blinder & Krueger, 2013; Wren, 2013). The literature shows that task routineness and offshorability are significantly intertwined,¹² and their interaction leads to varying distributional effects across sectors and occupational groups

(Ebstein et al., 2014; Goos et al., 2014; Kaihovaara & Im, 2020; Owen & Johnston, 2017). Therefore, a measurement of occupational offshorability¹³ is added as a control to the models (Blinder & Krueger, 2013), in the attempt to disentangle automation's distributional effects from globalisation. In addition, the battery of control variables includes classical sociodemographic items and, when required, possible labour market covariates.¹⁴ Country fixed effects are included in the models to control for contextual effects that are expected to be particularly relevant given the size coverage of the survey used.¹⁵

However, the hierarchical nature of the data requires further robustness checks. Although the interaction models allow for thoroughly exploring the cross-sectional and longitudinal heterogeneity in the data, I replicate the analysis using multilevel models with random intercepts at the country-occupational level,¹⁶ as workers are expected to share similar characteristics within country-specific occupational groups. Accessibility to laypeople and more parsimonious assumptions (Antonakis et al., 2021; Dedrick et al., 2009) prompted me to prefer OLS models—with standard errors clustered at the occupational level—over multilevel techniques as the main method of empirical investigation. As a further robustness check, I run OLS models with standard errors clustered at the country level and with different specifications of the dependent variables.¹⁷ Finally, I replicate the analysis using logit and probit models.¹⁸

¹⁰Central European/Bismarckian: AT, BE, DE, FR, NL; Anglo-Saxon/Liberal: IE, UK; Scandinavian/Social Democratic: DK, SE, FI; Southern Europe: IT, ES, PT, GR.

¹¹Data on year-specific trade union density at the national level are sourced from the OECD (available at <https://stats.oecd.org/Index.aspx?DataSetCode=TUD>). Although collective bargaining coverage may better capture the level of in-work protection, the differences in arrangements between countries (e.g., works councils, shop stewardship, etc.) can undermine comparability.

Data on year-specific average monthly amount of social benefits received by households in need—composed by two-parent family below the retirement age—are sampled from SPIN (Social Assistance and Minimum Income Protection Interim dataset:<https://www.su.se/social-policy-indicators-database/data?open-collapse-boxes=ccbd-socialassistanceandminimumincomeprotectioninterimdatasetsamip>). The variables selected are social assistance (“SAfa”) and minimum income protection (“MIPfa”). Main policies considered for each country varies, but “SAfa” is usually based on minimum income schemes, while “MIPfa” also includes housing supplement, refundable tax credits, and other benefits. Information is missing for Italy in 2010, 2012, and 2016 (while for other years data are sourced from MISSOC).

¹²In the ESS sample, one third of the most routine occupations (last two quintiles of RTI) are also coded as highly offshorable (last two quintiles of the corresponding index).

¹³To build this index, I rely on the country-year-specific dataset created by (Mahutga et al., 2018). Data are available at <https://matthewwcm.ucr.edu/data.html>. I averaged the scores by occupation across all European countries included with the ISCO08 code (AT [2013], CZ [2013], DK [2013], EE [2013], FI [2013], GR [2013], IE [2010], LT [2013], LU [2013], NL [2013], PL [2013], SI [2012], ES [2013], CH [2013]). The index is coded at ISCO88/08 three-digit level as for RTI.

¹⁴In all the models, I control for gender, years in full-time education, age (and age squared), trade union membership, domicile in rural areas, marital status, and children in the household. I also control for working hours and contract duration in the models run on low income (objective and subjective). Finally, I control for “objective” low income when running the models on perceived income security.

¹⁵Replications of the main models with time fixed effects are included in Table A2.3. No significant differences from the main results emerge.

¹⁶Occupational-level sets at two-digit ISCO groups.

¹⁷Different specifications of the dependent variables include more conservative measurements of objective and perceptual low income (i.e., only respondents in “paid work” and below the second decile of the income distribution, or perceiving not being able to cope on present income) and a less conservative measurement of part-time employment (i.e., below 35 working hours).

¹⁸I use the “glm” Stata command to include ESS weights in the models. The standard errors are clustered at the occupational level (three-digit ISCO). OLS regressions are used as main models to enhance understanding of coefficients, subsequently validated by logit and probit models.

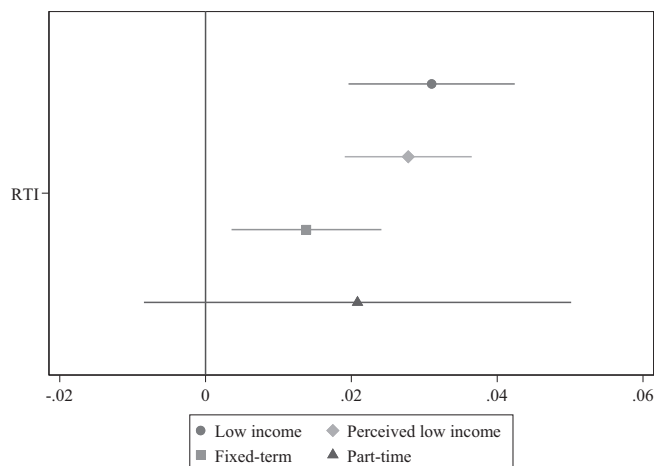


FIGURE 1 OLS models: Regression coefficients and 95% credible intervals. The models include the entire battery of controls (Table A2.1). *Source:* ESS waves 1–9 (2002–2018).

FINDINGS

The inferential results confirm the expected positive correlation between the exposure to automation risk and employment precariousness (H1). The graphical representations of the regression coefficients presented in this section refer to the main OLS models, equipped with the complete battery of controls and with standard errors clustered at the ISCO three-digit level¹⁹ (complete regression tables in Appendix A2, Table A2.1). The routineness of working tasks (standardised RTI) is positively associated with low income (objective and perceived), while also showing a weaker positive correlation with fixed-term contracts (Figure 1). These effects are largely confirmed in the robustness checks (Tables A2.2–A2.7, logit and probit models also show a positive correlation between RTI and part-time employment, barely significant with the multilevel model).

Looking at the controls (full regression tables in Appendix A2), women show a higher probability of ending up in a precarious job, in line with a consolidated literature on gender-based labour segmentation (Rovny & Rovny, 2017; Schwander & Häusermann, 2013). On the contrary, trade union membership and offshorability negatively correlate with all the occupational outcomes considered. While the sign of the first coefficient resonates with the literature on the softening effects of political-economic institutions on automation's impact (Oesch & Rodriguez Menes, 2011; Parolin, 2020), the negative effect associated with the offshorability index might come as a surprise. However, it should be recalled that

¹⁹No issue of multicollinearity is detected (with the obvious exceptions of age and age squared).

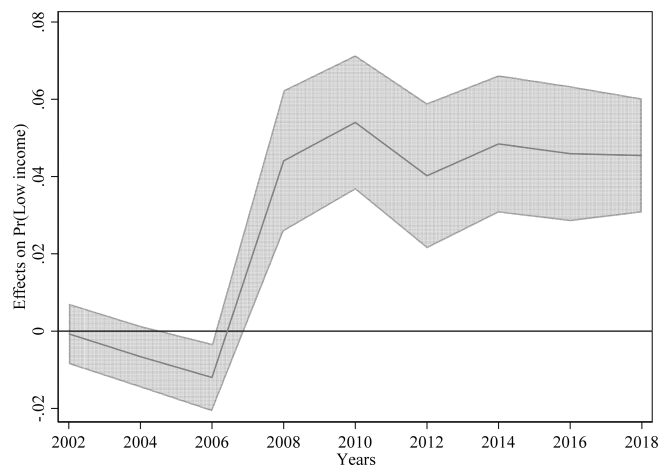


FIGURE 2 Longitudinal variation of the average marginal effect of RTI on low income (95% credible intervals) (Appendix A4). RTI, Routine Task Index. *Source:* ESS waves 1–9 (2002–2018).

highly educated professionals are among the most exposed to the risk of offshorability, particularly those that entail extensive usage of computers (occupation-based distribution of the offshorability index in Figure A1.2), hence showing a poor correlation with negative labour market conditions (Blinder & Krueger, 2013). Finally, being married with children, highly educated and living in a rural area negatively correlates with most of the outcomes considered.

Against H2, the positive association between automation risk and low income (both objective and perceived) is only weakly mediated by the rise of atypical employment among the automation “losers.” I run generalised structural equation models with RTI as the independent variable, low income (both objective and perceptual) as the dependent variable and fixed-term and part-time contracts as mediating variables (Appendix A3). While part-time contracts show no significant mediating function, below 5% of the positive effect of occupational automatizability on low income is mediated by fixed-term employment.

Concerning the longitudinal variation, I find partial confirmation of the expected worsening of automation's effect on employment precariousness after the Great Recession (H3). The average marginal effect of automation risk on low income turns from negative to strongly positive around the beginning of the financial downturn (2008, ESS4), without significant changes in the following editions of the survey (Figure 2 and Appendix A4). However, no significant trends of longitudinal variation are detected with regard to the correlations between automation risk and atypical employment.

The institutional configuration of political economies is found to significantly alter the relation between

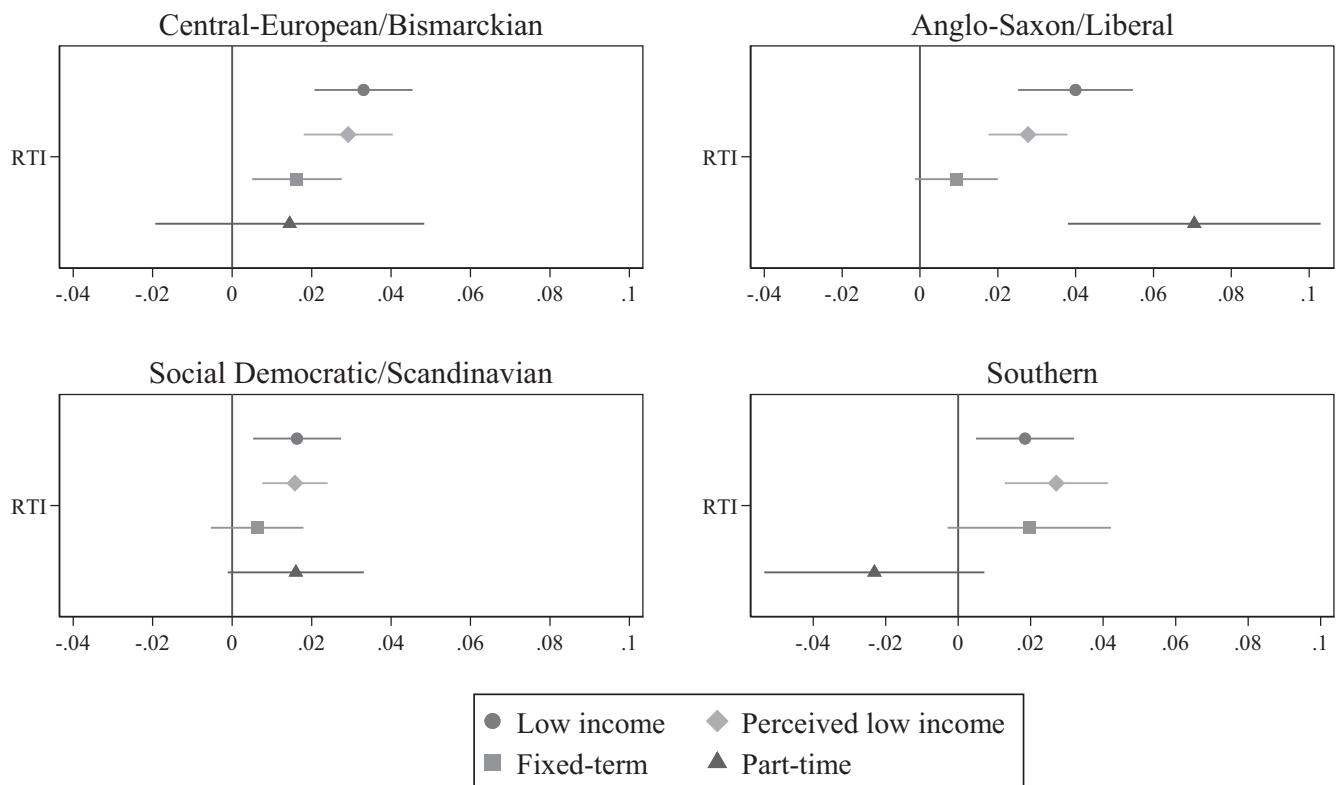


FIGURE 3 Split-sample OLS models: Regression coefficients and 95% credible intervals. The models include the entire battery of controls (Appendix A5). *Source:* ESS waves 1–9 (2002–2018).

technological replaceability and precarious employment. Nonetheless, the evidence does not confirm the expected cross-cluster variations (Figure 3 and Appendix A5). Against H4a, the positive correlation between automation risk and low income (objective and perceived) remains significant in all clusters, including the Scandinavian countries. Nonetheless, exploratory interaction analyses suggest that the Nordic universal wage-setting institutions may play a role in mitigating earnings losses among automation “losers,” as trade union density appears to curb routine workers’ slippage toward low levels of income (Appendix A7). Considering the operationalisation of income in relative terms presented in this paper, this moderating effect may be interpreted as evidence of a compressed earnings distribution resulting from strong labour-market institutions (Brady et al., 2013; Hope & Martelli, 2019). On the contrary, the positive interactions between generous social assistance and task routineness suggest that a flaw in the income-support system may be found in public transfer schemes (although the latter soften perceived economic insecurity, Appendix A8). Replications of the exploratory analyses, including OLS models with and without country and time fixed-effects and multilevel models with random intercepts at the country level, yield consistent results. Even so, these findings should be viewed cautiously, as

observational causal-inference approaches are needed for stronger validation.

More multifaceted evidence emerges with regard to atypical employment, showing fixed-term and part-time contracts as alternative patterns of precarisation of automatable occupations in Europe. In stark contrast with H4b, Central European routine workers are the most likely to be employed with a fixed-term contract, followed by the Southerners (although here the coefficient is barely significant and not significant in probit and logit models). However, there appears to be no association between automation risk and part-time employment in these countries, as opposed to a strong positive correlation detected in the Anglo-Saxon cluster and, much weaker, in Scandinavia (again, barely significant). Finally, exploratory interaction analyses suggest that high trade union density may significantly reduce the diffusion of fixed-term contracts among the automation “losers” (Appendix A7), while some model replications show the opposite effect on part-time employment (albeit very weak).

Overall, these former “insiders” (or internal segment) of the labour market, subject to the risk of automation, seem to encounter a cross-country shift toward atypical employment, mainly in the forms of reduced working hours in Anglo-Saxon and Scandinavian countries

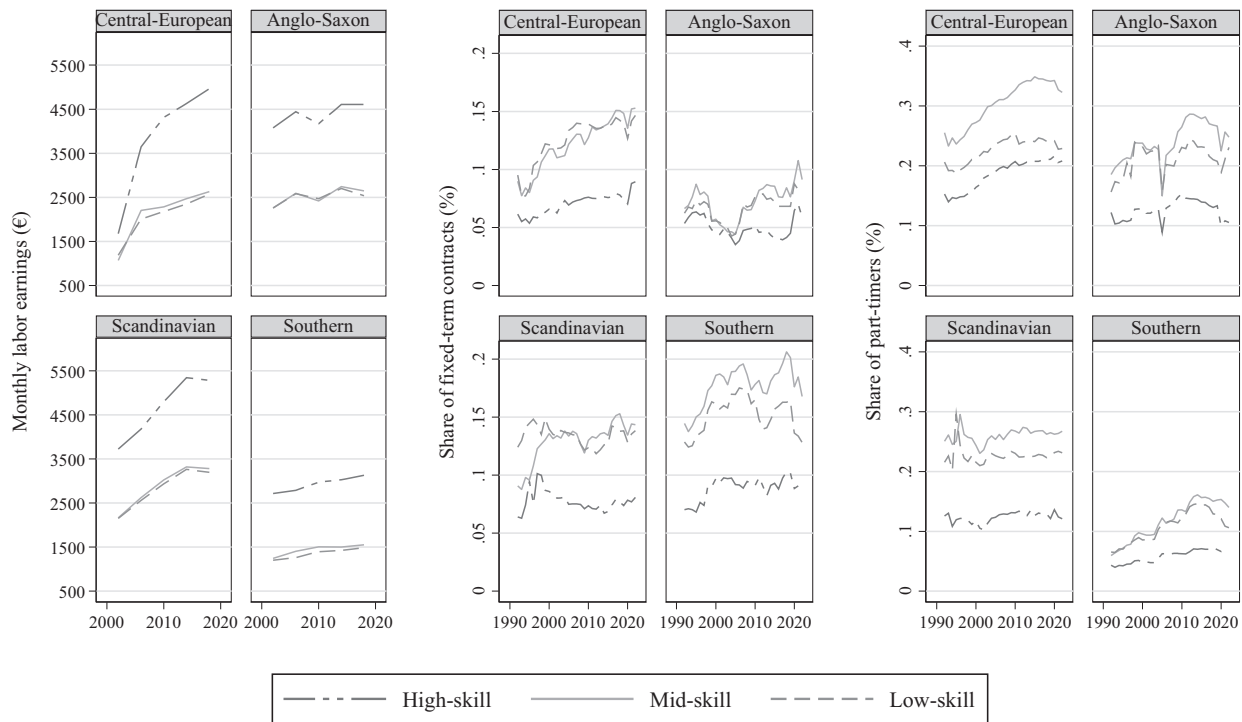


FIGURE 4 Mean monthly labour earnings (left quadrant), share of fixed-term contracts (central quadrant) and share of part-timers (right quadrant) in four clusters of European countries. *Source:* Structure of Earnings Survey (SES-Eurostat, 2002–2018) and Eurostat (1992–2020).

(although less robust in the second case) and temporary contract duration in Central and Southern countries (although the robustness checks suggest caution when commenting on the last cluster). Less variation is found with regard to low income, which seems to threaten all European routine workers. Robustness checks largely confirm these results (Tables A5.2–A5.4),²⁰ and longitudinal variations within each welfare cluster align with the overall sample (Appendix A6).

In sum, the exposure to automation risk is confirmed to be significantly associated with the chance of having a low income in spite of labour market participation across all of Western Europe, particularly after the Great Recession (2007–2009). The impoverishment of the automation “losers” does not seem to be primarily driven by a greater reliance on atypical contracts, although significant correlations between technological replaceability and non-standard forms of employment are detected in all political-economic clusters. Unfortunately, the lack of information on labour earnings in the survey precludes a

test of the mediating role of wage dynamics in the relation between automation risk and low income. Nonetheless, descriptive evidence based on the macro data from the SES-Eurostat (2002–2018) provides tentative support for that indirect relation (Figure 4). I clustered all typically routine occupations in one group, while separating the others between highly (e.g., professionals, technicians, etc.) and low-educated occupations (e.g., sales and service workers, etc.) due to their fundamental differences in tasks (Autor, 2015).²¹ Although the analysis is highly suboptimal due to the reliance on coarse-grained data, the average levels of task routineness of the occupational groups corroborate the tripartition, as mid-skill occupations only fall in the last two quintiles of the RTI distribution. Indeed, similar groupings are often used in task-based research on automation across different disciplines (Autor, 2015; Goos et al., 2014; Kurer, 2020;

²⁰The logit and probit models confirm these correlations, whereas the multilevel models undermine the positive effect of task routineness on both low income and part-time employment in Scandinavian countries.

²¹The three skill-based occupational groups are created by clustering one-digit ISCO08 classes as follows: high-skill group (managers, professionals, technicians and associate professionals), mid-skill routine (clerical support workers, plant and machine operators and assemblers, elementary occupations), low-skill (service and sales workers, skilled agricultural, forestry and fishery workers, craft and related trades workers).

Kurer & Gallego, 2019; Kurer & Palier, 2019). A stark divergence emerges between growing labour earnings among high-skill professions and stagnating wages among both mid-skill routine occupations and low-skill nonroutine jobs across all clusters of the European political economies (particularly in Central Europe, country-level distribution in Appendix A9).²²

Therefore, a scenario between the skill-biased and the routine-biased predictions appears to lay behind the rise of low income among the automation “losers.” The latter share similar sluggish wage conditions with manual non-routine workers, downgrading their position in the income distribution following the earnings leap of high-skill professionals. A similar pattern characterises the distribution of atypical employment along the educational ladder (Eurostat, 1992–2020), with a growing divergence between full-time/open-ended contracts among highly educated occupations and part-time/fixed-term arrangements among both mid- and low-skill occupations. Surprisingly, routine occupations show, on average, a larger share of atypical contracts than low-skill manual occupations. Overall, this descriptive evidence corroborates the inferential findings, showing that the rise of work precariousness associated with the transition toward the knowledge economy is not confined to low-skill jobs, affecting mid-skill occupations at risk of technological substitution as well.

DISCUSSION AND CONCLUSION

This paper investigates the correlation between occupational exposure to automation risk and employment precariousness, proposing a task-based lens to study the European labour markets' segmentation that occurred over the last four decades. I posited that mid-skill routine workers, under the increasing pressure of technological replaceability, encounter downgraded working conditions, particularly in the forms of low income and atypical contracts. The empirical analysis relies on a large

sample from ESS (2002–2018), and it confirms the expected positive correlation between occupational routineness and the probability of having a (relative) low income, particularly after the Great Recession (2007–2009). The effect of technological replaceability on atypical employment shows, instead, great variation across the clusters traditionally adopted to classify European political economies. Automation risk is significantly correlated with part-time employment in Anglo-Saxon countries and, in Scandinavia, while the precarisation of routine occupations is mainly driven by fixed-term contracts in Central and Southern Europe. Finally, since the mediation analysis discards the rise of atypical employment as a crucial driver behind the impoverishment of the automation “losers,” I turn to supplementary descriptive evidence based on aggregate data from SES-Eurostat (2002–2018) to evaluate tentatively whether different wage dynamics among occupational groups may account for a such a shift. What emerges is a divergent trajectory between the growing labour earnings of high-skill professionals and the stagnating wages of both mid-skill routine and low-skill manual workers across all countries' clusters.

Overall, these findings show that work precariousness is not only confined to low-skill labourers, but also characterises former “insiders” of the European labour markets. As suggested by the literature on the knowledge-economy transition, servitisation alone cannot explain the structural economic changes of the last four decades. The advent of information technologies is an analytically distinct driver of economic transformations, which bears relevant distributional consequences for the once-secure mid-skill occupations. The Great Recession proves to be a critical juncture in labour automation processes (Jaimovich & Siu, 2012), permanently deteriorating the position of routine workers in the labour market. The lack of earnings recovery for these workers suggests that their marginalisation, possibly accelerated by cost-competitiveness motivations during the economic downturn (Erhel et al., 2022; Piasna, 2017), is the result of a long-lasting change in labour organisation. Specifically, the labour-unfriendly usage of automation technologies during the economic crisis may have significantly altered the organisation of workflows and production processes, resulting in an irreversible decline in the wage premium for mid-skill occupations, thus widening labour market segmentation. Against expectations, the striking impoverishment of this segment of the workforce does not appear to be significantly mediated by the diffusion of different forms of atypical employment, which is, instead, highly conditional upon the political-economic institutional setup.

²²Each political-economic cluster is composed by the following countries: Central European/Bismarckian (AT, BE, FR, DE, NL), Anglo-Saxon/Liberal (IE, GB), Scandinavian/Social Democratic (SE, NO, FI, DK), Southern (IT, ES, PT, GR). Note: Denmark is missing in the data on monthly earnings.

Data on monthly labor earnings available at: https://ec.europa.eu/eurostat/databrowser/product/view/EARN_SES_MONTHLY.

Data on fixed-term contracts available at: https://ec.europa.eu/eurostat/databrowser/view/LFSA_ETGAIS_custom_7529546/default/table?lang=en, https://ec.europa.eu/eurostat/databrowser/view/LFSA_EGAIS_custom_7532645/default/table?lang=en.

Data on part-time contracts available at: https://ec.europa.eu/eurostat/databrowser/view/LFSA_EPGAIS_custom_7533528/default/table?lang=en.

More broadly, this study provides an empirical picture that shows the complementarity between the skill-biased and the routine-biased technological frameworks. Although the allocation of high-quality jobs among the most educated workers resonates with SBTC, the latter needs to be complemented with a task-based framework of labour market segmentation in order to adequately account for the downgrading socioeconomic conditions of mid-skill workers. In other words, neither a monotonical increase of job quality along the skill distribution, nor a U-shaped trend; what emerges is a “recalibrated” dualisation in Western European labour markets, with low labour earnings and atypical contracts diffused among both low-skill nonroutine labourers and routine workers provided with an intermediate level of education and, on the other hand, well-paid and stable jobs reserved for high-skill professionals only. Nonetheless, recent studies aimed to develop new measurements of task automatability based on Generative AI functions suggest that the new software may extend automation pressures to cognition-intensive occupations—especially those that entail technical and less abstract tasks (e.g., IT engineers) (Eloundou et al., 2023; Felten et al., 2023; Tolan et al., 2021). Therefore, we can speculate on the stability of the picture presented in this paper, as the employment quality of some high-skill professionals might be threatened in the near future.

Although the findings presented appear quite robust, no causal interpretation can be drawn from the correlational nexus between routineness and precariousness here described. Such an ambitious conclusion needs the support of panel-data evidence that would better track the occupational trajectories of routine workers, capturing the within-individual transition toward atypical and low-paid jobs. Future research should also investigate whether the sociodemographic background of mid-skill workers affects their occupational trajectories, which might contribute to the gender-based and nationality-based segregation of the labour market, as female and foreign routine workers may face a more pronounced downward shift toward low-skill and low-paid jobs (Murphy, 2014). Furthermore, the reader might be interested in knowing more about the strategic behaviour of these workers in the labour market, possibly being interested in changing occupational sector following the downgrading of routine occupations. The extant literature provides poor evidence in support of this scenario, showing limited mobility of routine workers (Kurer, 2020; Kurer & Gallego, 2019), together with a negative correlation between employment polarisation and collective bargaining coverage (Meyer & Biegert, 2019). Therefore, routine workers seem prone to accept worse contractual conditions under intense

pressures for labour automation, although panel-data analyses are needed to effectively address this puzzle.

A second limitation of the present work concerns the supply-side approach, embedded in the RBTC framework, that overlooks the endogeneity of labour automation. Focusing on the task composition of the workforce provides an effective estimation of individual potential exposure to replaceability, without providing any information either on the actual deployment of new technologies in the workplace or, more in general, on the organisational context where these workers are involved (Cetrulo et al., 2024; Cirillo et al., 2021; Montobbio et al., 2023). Some scholars have recently proposed focusing on the firm level so as to encompass the local nature of production in automation studies (Bessen et al., 2025; Küstermann, 2022). From these contributions, there emerges a crucial mediating role played by business strategies and production organisation, showing a sluggish technological innovation in small firms that, in addition, is generally pursued as a means to improve product quality without labour disruption (Waldman-Brown, 2020). An opposite strategy to deal with the endogeneity issues of this research domain relies on causal-inference techniques (Autor & Dorn, 2013; Klenert et al., 2022), that can be used to test the impact of a (partially) exogenous automation shock on employment precariousness, possibly disentangled from concurrent structural economic transformations (e.g., globalisation). In this regard, deeper investigation should be dedicated to offshorable routine occupations, exploring the multifaceted interaction of technological replaceability with the risks and opportunities associated with international tradability.

Similar methods can also be employed to test the effects of specific political-economic institutions on the precarisation of mid-skill occupations. The exploratory interaction analyses suggest that the even diffusion of low income across the entire European routine workforce might be traced back to poor buffering capabilities of assistance-based transfers, whereas strong trade unions seem to improve their employment conditions, particularly compressing the earnings distribution (Brady et al., 2013; Hope & Martelli, 2019). However, observational causal-inference designs are needed to enhance the investigation of the moderating effects of single interventions and institutions. The preliminary evidence presented in this paper—which should be approached with great caution—suggests focusing on in-work benefits as instruments to enhance the outreach of income-support schemes that, in combination with training opportunities and coordinated systems of technological innovation, are expected to significantly improve at-risk workers' economic conditions and occupational opportunities (for a review of the policy responses to automation, see

Bürgisser, 2023).²³ Furthermore, it should be also investigated whether contract flexibilisation is purely driven by employers' cost-efficiency concerns or if the reliance on atypical contracts is included in a consociational strategy that guarantees job protection and training services to the targeted workers. This line of research might unveil different causal stories behind the rise of part-time contracts in Nordic and Anglo-Saxon countries (as also indicated by the weak positive effect detected in some interaction models with trade union density).

In conclusion, this analysis seeks to expand the understanding of automation's distributional consequences, as a source of socio-economic threat for typical "insiders" of advanced labour markets. Such research endeavour is particularly relevant for the expected behavioural implications associated with the diffusion of economic insecurity among workers once bestowed with comparatively high standards of protection and employment conditions. The "losers" of automation used to belong to the Fordist middle class, which, up until the 1980s, had benefited from generous social protection, opportunities for upward mobility and great relevance in the political arena (Esping-Andersen, 1990; Iversen & Soskice, 2019; Kurer & Palier, 2019). Political scientists show that the risk of technological replaceability is associated with concerns over social status decline, which prompts rising support for the radical right (Anelli et al., 2019; Kurer, 2020). Given that only a weak unemployment risk is generally associated with automation (Kurer & Gallego, 2019), the precarisation process just described may reasonably account for the structural driver behind the "losers" discontent, to be tested in future research.

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CONFLICT OF INTEREST STATEMENT

The author declares no conflicts of interest.

²³To our knowledge, Parolin (2020) is the only counterfactual study on the impact of unionization on the occupational consequences of automation.

DATA AVAILABILITY STATEMENT

This study relies solely on open-access data available from the websites of the European Social Survey (ESS), Eurostat, OECD, and Social Policy Indicators (SPIN), as well as from the personal website of Matthew C. Mahutga. However, the author is not permitted to share the data related to the Routine Task Index.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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