University of Antwerp
AIPRIL | Centre of Excellence

BLAME THE ROBOTS? ROUTINE-BIASED TECHNOLOGICAL CHANGE AND THE RECENT DECLINE OF UNION MEMBERSHIP IN EUROPE AND THE UNITED STATES

Henri Haapanala, Zachary Parolin and Ive Marx

Working paper

No. 22/05

February 2022

CSB Centrum voor Sociaal Beleid Herman Deleeck Universiteit Antwerpen
CSG Centre for Urban History University of Antwerp
IOB Institute of Development Policy University of Antwerp

BLAME THE ROBOTS? ROUTINE-BIASED TECHNOLOGICAL CHANGE AND THE RECENT DECLINE OF UNION MEMBERSHIP IN EUROPE AND THE UNITED STATES

***Henri Haapanala*[a]*, Zachary Parolin*[b, c] *& Ive Marx*[a]**

[a] Herman Deleeck Centre for Social Policy, University of Antwerp
[b] Department of Social and Political Sciences, Bocconi University
[c] Center on Poverty and Social Policy, Columbia University

Working paper No. 22/05

February 2022

Abstract

Union membership has strongly declined in advanced democracies in recent decades. One perspective argues that structural forces, such as routine-biased technological change and automation, have contributed to the decline of unionization. Other perspectives instead point towards political and institutional explanations. We attempt to adjudicate these competing claims using data from the European Social Survey and US Current Population Survey (2002 to 2018) and exploratory case studies from Germany, Finland and the United States. Applying three sets of methodological approaches and two measures of automation, we consistently find that routine-biased technological change is not a meaningful determinant of declining union membership from 2002 to 2018. Our results suggest that (1) occupations at greater risk of automation do not have a significantly higher likelihood of unionization, (2) automation exposure has no significant association with changes in union membership, and (3) declining shares of routine-intensive manufacturing employment have acted to reduce the severity of membership decline. Instead, our case studies suggest that the effect of technological change on union membership is mediated through country-specific collective bargaining institutions and the power relationship between management and labour.

Keywords: trade unions, technological change, comparative social policy, mixed-methods, EU-US social policy, labour markets

Acknowledgements: The authors extend their thanks to the seminar participants at the 27th International Conference of Europeanists (online, June 2021) and colleagues at the Antwerp Interdisciplinary Platform for Research Into Inequality (AIPRIL). Henri Haapanala gratefully acknowledges the support of Research Foundation Flanders, grant number G017520N.

INTRODUCTION

To what extent does technological change explain the recent decline of union membership in the advanced democracies? Scholars have been split on this question. On one hand, some studies suggest that routine-biased technological change (RBTC), namely the automation of blue-collar manufacturing occupations with industrial robots, has mechanically reduced the number of unionized workers. Other studies, in contrast, point to political and institutional changes affecting worker incentives to unionize and unions' ability to recruit and maintain members. This study attempts to adjudicate these competing perspectives using micro-level data on union membership in 19 countries, a broader set of empirical tools than prior studies have applied, and detailed case studies of three advanced economies with major manufacturing sectors and different sets of labour market institutions.

The origins of declining union membership are relatively well-documented. Starting in the late 1970s, organized labour in advanced democracies faced the perfect storm of neoliberal economic thinking embodied in Thatcher and Reagan, globalization and deindustrialization undermining the principles of strongly regulated blue-collar employment, and the proverbial 'end of history' with the collapse of state socialism leaving seemingly no alternatives to market liberalism (Ebbinghaus and Visser 1999, Ost 2009).

What is less obvious, however, is why union decline has persisted into the twenty-first century despite the shortcomings of the neoliberal era becoming ever more manifest. Top 10% and 1% shares of income and wealth are at record-high levels while wages, job security, and social protection are under pressure, especially for low- and middle-skilled workers. Manufacturing occupations which have historically provided well-paid, secure employment for masses of blue-collar workers have been displaced by automation and off-shoring (Autor et al. 2015). One perspective might view unions as more attractive, given their role acting as a countervailing power against capital.

Instead, the opposite has occurred. Union membership has declined in most advanced democracies, albeit with notable variation in rates of change. These patterns invite the question: why has unionization fallen in the first place? And why has this happened more in some countries as opposed to others? Many competing explanations have been put forward, none quite satisfactory. Scholars have recently posited that routine-biased technological change may be among the primary culprits of declining union membership; thus far, however, empirical evidence on these claims is scarce. Studies investigating the link between RBTC and organized labour have primarily looked at country-year means in union membership and shares of employment at high risk of automation (Meyer 2019). In contrast, this study uses individual-level data on union membership and a novel dataset on industrial robots to obtain indicators of automation exposure. We posit that RBTC can act either *directly* or *indirectly* in shaping union membership. Directly, labour-saving technologies might reduce the employment shares of occupations at greater risk of automation, displacing unionized workers. Indirectly, technological change can raise fears of unemployment and redundancy, encouraging workers to unionize out of concern for the future of their jobs.

This study applies a mixed-methods design to investigate the effects of RBTC on union membership, combining statistical analysis of 18 European countries and the United States from 2002-2018 with case studies of industrial robot applications in countries with varying trade union membership, namely Germany, Finland and the US. We find consistent evidence against the claim that RBTC has acted to reduce union membership. Instead, our findings suggest that union membership in Europe in 2018 would be even lower had the shares of industry-sector and routine employment not declined since 2002. Specifically, our findings can be summarized as follows:

First, RBTC appears to have very little direct effect on unionization. Using two different measures of automation exposure, we find no evidence of a negative, statistically significant effect on union membership from 2002 through 2018.

Second, we find that changes in the occupational composition of labour markets have had on average a dampening effect on the decline in union membership; thus, to the extent that RBTC has displaced routine-intensive industry-sector employment, our evidence suggests that these shifts in employment patterns have contributed to a less intensive membership decline than would have been the case with the preservation of routine employment. Among the occupational categories with the highest likelihood of union membership, we find non-routine cognitive occupations including teaching and health professionals.

Third, we point instead to political, institutional and other structural explanations of union decline through detailed case studies of industrial unions in Germany, Finland and the US. These cases suggest that instead of RBTC driving union decline, its impact is mediated through collective bargaining institutions and the power relationship between management and labour. In brief, trade unions are not passive onlookers to RBTC, but use their agency to influence the labour market outcomes of automation.

BACKGROUND

Understanding Union Decline

Labour unions have been at the core of theories relating to class-based political struggle. In Korpi's (1983) 'power resources theory', for example, unions are key to mobilizing working-class and lower-income voters, forming coalitions with political parties, and pressuring governments to implement more egalitarian social and labour market policies (Huber and Stephens 2001). Decades of empirical evidence support these claims. Unions reduce income inequality not only by compressing market earnings, but also through their influence in advocating for more generous redistributive policies. Stronger trade unions in a country have been associated with lower levels of income inequality, smaller likelihood of in-work poverty (Brady et al. 2013), more generous social policies (Western and Rosenfeld 2011), positive spillover effects to non-union members (Denice and Rosenfeld 2018), and are often cited as one explanation of why the EU tends to have more egalitarian income and wage distributions relative to the US (Garnero 2021).

The starting points of deunionization in the advanced economies – the end of the Keynesian hegemony, full-employment economic policy, and the decline of blue-collar manufacturing – are relatively well-known in the industrial relations literature (Ebbinghaus and Visser 1999, Checchi and Visser 2005). However, research on the *persistence* of union decline in post-industrial times is limited. The working populations in Europe and North America are facing several new grievances the likes of which have historically given rise to worker mobilization (Ibsen and Tapia 2017). As a non-exhaustive overview, working conditions and the protection of labour from market forces have weakened in the last two decades through the expansion of precarious work on zero-hours or temporary contracts, an increasing emphasis for formal qualifications, the weakening and increased conditionality of unemployment benefits, and computer-centred innovations in management and human resources such as stringent and continuously monitored performance targets (Standing 2013). Despite these changes, union membership has continued to steadily decline in most advanced democracies, with many countries at record low levels (OECD and AIAS 2021). The puzzling weakness of organized labour at a time when it remains desperately needed has started to gain renewed scholarly attention. Recent contributions include Meyer (2019) and Meyer & Biegert (2019), who posit that routine-biased technological change reduces union membership.

We review two prominent theoretical arguments of union decline – politics and institutions versus RBTC and automation – to bridge these literatures and reassess the role of technological change in a holistic perspective.[1] Placing these arguments on an equal footing with each other enables us to compare their relative importance in the puzzle of union decline.

Politics and Institutions

The political-institutional approach highlights the role of public policy, employee-employer power dynamics, and the configurational setup of bargaining institutions in affecting union membership. In the US, for example, nearly half of workers live in a state with Right to Work (RTW) laws, which restrict the capacity of unions to collect dues and recruit new members. In the European Union, the Ghent system of union-administered unemployment insurance is a central incentive to unionize. In countries with the Ghent system[2], union membership tends to have higher levels and decline more slowly, even though the administrative role of unions has been undermined by independent unemployment funds and the rising conditionality of unemployment benefits (Høgedahl and Kongshøj 2017).

The configurational setup of bargaining institutions involves dimensions such as centralization of collective bargaining, wage coordination between sectors, and ability of firms to derogate from collective agreements. Grouping countries according to these indicators suggests highest institutional power for unions in the Nordic countries, Belgium, Netherlands, Germany and Austria; the middle ground includes countries such as Switzerland, France, Italy, Spain and Portugal; and the weakest union strength in Central-Eastern Europe, Ireland, the UK and US (Garnero 2021). This grouping closely corresponds to other regime-types developed in comparative research, such as varieties of capitalism and welfare state regimes. Indeed, trade

[1] A third set of arguments explaining union decline focuses on social customs, socio-cultural and inter-generational change. Micro- and multi-level analyses of union membership have to take into account individual and workplace-level factors such as the effects of individualization and social norms in the workplace. While a comprehensive analysis of these arguments is beyond the scope of this paper, we refer the interested reader to papers suggesting high rates of trade union support among young and precarious workers, people born after 1980, and in workplaces where unionization is an established social custom (Palm 2017, Ibsen et al. 2017).

[2] Ghent countries are Belgium, Denmark, Sweden and Finland.

unions have had substantive political influence in the formation of labour markets and welfare states, with stronger organized labour movements able to establish solidaristic and robust institutions (Korpi 2006).

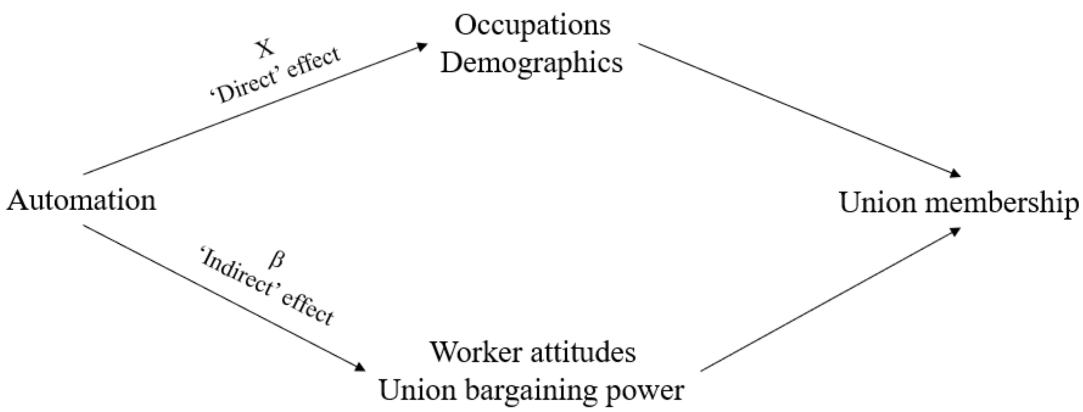
Large-scale societal changes are central to the political-institutional narrative. Over the 1970s and 1980s, the end of the Keynesian economic paradigm and liberalization of capital and goods markets severely undermined the position of blue-collar manufacturing workers (Ibsen and Tapia 2017). Trade unions have historically had their largest shares of membership and influence in the manufacturing sector. In firms with tens or hundreds of workers sharing similar skill levels, working hours and career trajectories, plenty of bargaining points arise which the workforce can agree to stand behind and authorize a union representative for collective negotiations. In contrast, 'non-standard' employment relationships widespread in the modern service sector are more challenging territory for unions, who struggle with the recruitment and retention of workers in piecemeal careers with multiple different employers, irregular working hours and fluctuating incomes (Keune and Pedaci 2020). In brief, the political-institutional perspective suggests that workers' decision to unionize is predominantly determined by pragmatic factors such as union presence in the workplace or capacity to defend wages and working conditions. Routine-biased technological change only enters this picture to the extent that it weakens the bargaining power or political influence of unions.

Automation and Technological Change

In contrast to the political-institutional perspective, theories of automation as a culprit of union decline are generally built atop of economic models of routine-biased technological change, which suggest that labour-displacing technologies such as industrial robots contribute to declining employment shares of 'routine' occupations. High routine task intensive (RTI) occupations, the most susceptible to automation, tend to be in the middle of the wage and skill distributions and have thus been central to research on job polarization (Acemoglu and Autor 2011). Though the decline in employment shares of high-RTI occupations has been written about extensively in the context of the US, evidence suggests that this trend is also pervasive throughout Europe (Goos et al. 2014, Dauth et al. 2021).

Figure 1 presents a simple framework for understanding the pathways through which RBTC is most likely to affect union membership.

Figure 1. Pathways connecting routine-biased technological change (RBTC) to changes in union membership.



The 'direct' pathway, labelled with *X*, operates through reductions in employment shares of automation-exposed occupations. This pathway is perhaps the most-cited explanation of the effect of RBTC on union membership (Acemoglu et al. 2001, Meyer 2019). Given that blue-collar manufacturing was a bedrock for organized labour during the 20th century, automation may contribute to a mechanical decline in union membership through the displacement or (early) retirement of predominantly male, blue-collar, high-RTI workers in manufacturing. This pathway relies firmly on the testable assumption that workers at greater risk of automation are more likely to be unionized.

On the other hand, RBTC has also resulted in the proliferation of complex industry-sector occupations such as engineering and robot programming which require high levels of education and command high wages. In other words, RBTC may increase the socio-economic profile of the average industry-sector worker, resulting in changing attitudes and preferences regarding bargaining outcomes. To this effect, Becher and Pontusson (2011) remark that the average union member in almost all Western European countries earns an income above the national median, and the earnings premium has increased over time. Additionally, many industrial unions have addressed their post-industrial membership decline by merging with unions representing white-collar or non-manual workers, resulting in more heterogeneous member bases (Visser 2012: 137). This implies that the declining number of high-RTI workers, mechanically reducing union membership, can be compensated by increasing unionization among non-routine workers.

The 'indirect' pathway, labelled as β in Figure 1, suggests that RBTC affects the likelihood of union membership for any given worker, independent of changes in employment shares of their occupation or sector. Put differently, even if there were no change in the share of jobs at risk of automation, RBTC may nonetheless alter an individual's likelihood of unionizing. This can occur through several different mechanisms. Here, we outline three negative and two positive indirect channels of influence.

First, RBTC may increase skill or task heterogeneity of workers within firms and sectors, reducing the social bonds that are often necessary to successfully organize. As argued by Meyer and Biegert (2019), automation not only crowds out semi-skilled manual workers, but also increases the distance between low-skilled and high-skilled workers. Since low-skilled workers express strong preferences for redistribution and wage equality but high-skilled workers accept wage inequality, it is unlikely that the same union can represent both worker groups. This has the effect of reducing overall membership (Meyer and Biegert 2019: 5).

Second, RBTC may contribute to greater geographic dispersion of workers, similarly reducing their ability to effectively organize. This is most evident in sectors such as transport and food delivery relying on platform and on-demand work, where workers are often anonymous to each other or compete against one another for gigs (Bertolini and Dukes 2021). In sectors where firms employ small numbers of workers or interaction between colleagues is limited, for instance due to extensive automation, unions have to spread their organizational resources more thinly which increases their costs per recruited member (Keune and Pedaci 2020).

Third, RBTC may reduce the bargaining power of labour, reducing the incentives of workers to make claims on scarce resources particularly in occupations which are easiest to automate (Meyer 2019). The share of tasks in which automation out-performs labour continues to expand with advances in technology. If employers have to factor in the economic cost of industrial action or rent-seeking bargaining, this will further reduce the share of tasks which are more economical to perform with labour rather than automation (Acemoglu et al. 2001). In other words, an aggressive defence of wages and working conditions for automation-exposed workers can accelerate their displacement.

The first three mechanisms all imply a reduction in the likelihood of unionization. However, the fourth and fifth mechanisms outline positive indirect effects of RBTC on union membership.

Fourth, the perceived threat from technology may make workers *more*, not less, likely to unionize. Research shows that workers who perceive automation as a risk to their occupations or social status are likely to support protective labour market policies (Im and Komp-Leukkunen 2021). In this light union membership can become more attractive for at-risk workers, since unions are able to support workers in negotiations over the introduction of new technologies by eliminating information asymmetries between labour and management (Berg 2019).

Fifth, RBTC can reinforce a high-unionisation, low-inequality equilibrium, such as that in the Nordic countries (Chauvel and Schröder 2017). When unions uphold high entry-level wages through collective agreements, low-skilled labour becomes effectively priced out of manufacturing, resulting in employers providing extensive training for entry-level workers who become skilled operators. The Industrial Union of Finland finds that young and male industrial workers in particular think positively about robots and digital technologies, as they reduce physical effort, provide more interesting job tasks, and increase skill requirements and wages (Anttila 2021). In brief, it is possible for labour and technology to find a mutually beneficial relationship, where union members vote for rather than against the introduction of robots.

In sum, the direct and indirect effects of RBTC on union membership push in different directions. *Directly*, we expect RBCT to reduce the number of high-RTI industrial workers relative to low-RTI workers in the industry and service sectors, all of whom have different probabilities of unionization. *Indirectly*, we expect RBTC to affect the bargaining power of unions and individual preferences regarding unionization, as the cost-benefit calculation of unemployment risk and unions' ability to affect labour market outcomes evolves. We now proceed to introduce the methods with which we chart out the direct and indirect pathways, namely, statistical analysis of RBTC and union membership using micro-level survey data and case studies of industrial unions in Germany, Finland and the US.

DATA & METHODS

Conceptualizing Union Membership and Automation

Our dependent variable, union membership, is a binary variable for whether the respondent is currently registered as a union member. Using self-reported unionisation variables is preferable to the alternative of macro-level union membership data as it enables micro-level analyses with data that is comparable between countries. Union membership statistics at the macro-level carry a risk of bias from unions reporting inflated numbers (Kelly 2015). However, focusing on union *membership* provides only one, and rather limited, viewpoint into the theoretically distinct concept of union *power*. Our analysis therefore does not make claims to address every possible source of union power but is concentrated on membership as a directly measurable and observable indicator.

Our key explanatory variable is exposure to automation which we use to proxy RBTC. We apply the two most commonly used measures of automation exposure, the *routine task intensity (RTI)* index and indicators of *robot exposure*. RTI measures the routineness of occupations based on task content, where 'routine' tasks can be 'accomplished by machines following explicit programmed rules' (Autor et al. 2003: 1283). This index is widely used as an indicator of jobs and tasks at highest risk of displacement by automation (e.g. Autor and Dorn 2013, Goos et al. 2014, Frey and Osborne 2017, Blanas et al. 2019). High-RTI occupations are not limited to manual routine tasks such as lifting and carrying, but also include repetitive cognitive tasks such as call centre work, or machine-learnable tasks such as driving (Frey and Osborne 2017). RTI is useful for comparing the automation risk of occupations within and between sectors, but it has limitations particularly on the longitudinal dimension since the specific tasks associated with occupational titles frequently change over time, often as a result of RBTC eliminating the most 'routine' aspects within occupations (Haslberger 2021).[3]

On the other hand, we can directly measure the prevalence of automation with indicators of *robot exposure* or *robot penetration* (eg. Dauth et al. 2021, Graetz and Michaels 2018, Acemoglu and Restrepo 2019, 2020). These estimate the exposure of workers to industrial robots, defined as 'automatically controlled, reprogrammable, multipurpose manipulators programmable in three or more axes … for use in industrial automation applications' (IFR 2020). Robot exposure in our sample of countries has increased from an average of 0.9 robots per 1,000 workers in 2002 to 2.5 in 2018, signalling a rise in the intensity of automation both in the aggregate economy and specifically in the manufacturing sector.

[3] For instance, the occupation of bank teller has persisted in some form over time although the routine tasks of cash deposits and withdrawals are performed by ATMs. Modern bank tellers perform non-routine tasks such as customer service and consultation.

Data

We use data from 18 European countries[4] and the United States, merging the 9 biennial waves of the ESS for the years 2002-2018 with the US Current Population Survey. These micro-level datasets include variables on union membership, occupation and sector of employment, and demographic and household information. Our sample consists of individuals aged 18-65 in dependent employment or unemployed and actively seeking employment. The number of observations ranges from 454 to 206,496 per country-year, with a mean of 11,662 observations. We adjust the weights such that each country-year has the same proportional weight, while retaining the within-country-year weighting schemes to ensure representativeness. This ensures that countries and/or years with larger populations do not dominate our findings simply due to their larger size. Detailed descriptive statistics by country-year are available in Appendix I.

We measure RTI at the level of 2-digit ISCO-88 occupational codes (Mahutga et al. 2018). This means that for each individual we project the routineness of their broad occupational group, such as "customer service clerks" or "metal, machinery, and related trades workers". In total there are 27 such groups.

Robot exposure is operationalized at the country-year level following Equation (1).

$$Robot\ exposure_{ct} = \frac{Operating\ stock_{ct}}{'000s\ of\ workers_{c,t=1995}} \quad (1)$$

In other words, the year-specific stocks of industrial robots are standardized to the number of workers in baseline year 1995. This follows established procedures in the literature, with the aim of neutralizing the effect of labour market inflows and outflows from the effect of changes in the number of industrial robots (Acemoglu and Restrepo 2020). Data for robot stocks is sourced from the IFR, and the aggregate number of workers from the EU database on capital, labour, energy, material, and service inputs (EUKLEMS). Using an external source for employment statistics, instead of aggregating micro-data, should reduce potential measurement error and concerns regarding changes to industry codes over time.

Methods

After displaying descriptive statistics, we will apply three sets of techniques to understand how RBTC affects union membership. In broad terms, these approaches include (1) a linear

[4] Austria, Belgium, Czechia, Germany, Denmark, Spain, Finland, France, Hungary, Ireland, Italy, the Netherlands, Poland, Portugal, Sweden, Slovenia, Slovakia, United Kingdom

probability model estimating the effect of automation exposure on union membership, (2) a semi-parametric decomposition technique pulling apart the direct and indirect effects, and (3) case studies of automation and organized labour in three countries with differing labour market institutions. We now discuss these approaches in more detail.

First, we estimate a straightforward linear probability model to identify the association of within-country variation in automation exposure and within-country variation in union membership. Specifically, we estimate:

$$Union_{ict} = \beta_1 Automation_{ct} + \beta_2 Ind_{ict} + \beta_3 Trade_{ct} + \alpha_c + \tau_t + \varepsilon \quad (2)$$

In Equation (2), the outcome is a binary indicator of union membership for a given individual (i) in a given country (c) and year (t). Vector *Ind* includes a set of individual control variables including age, education, sex and sector of employment. At the country-level we control for exposure to foreign trade as a percentage of GDP. We include a full set of country and year dummies (α_c, τ_t) to account for stable differences between countries and common trends over time. $Automation$, our primary term of interest, is specified in two ways: with the robot exposure and RTI indicators respectively as described above.

While Equation (2) informs us of the association between automation and union membership, it does not differentiate between the *direct* and *indirect* effects, operating via employment shares and unobserved individual characteristics respectively. To identify these channels, we apply a semi-parametric decomposition technique. Two types of decomposition are often used in such analyses: Kitigawa-Oaxaca-Blinder (KOB) decompositions and DiNardo, Fortin, and Lemieux (DFL) reweighting decompositions. Both are similar in their underlying aims, to identify the share of change in union membership that is 'explained' by our covariates, as opposed to 'unexplained', but we employ the latter as it offers more flexibility (DiNardo et al. 1996). The DFL decomposition reweights the sample of labour market participants in a given year (say, 2018) to match the demographic and labour market composition (i.e. employment shares, age, gender, and education) of our initial year of interest (2002). Specifically, the reweighting function is defined as:

$$\psi(x) = \frac{Pr(t_x=2002|x)}{Pr(t_x=t|x)} \cdot \frac{Pr(t_x=t)}{Pr(t_x=2002)} (3)$$

in which t_x is the probability of being in year *t* conditional on routine task intensity, occupation (two-digit ISCO-88), sector of employment, age, gender and education in vector x. We estimate this independently for each country using a Probit model. We multiply the given weights in the ESS by the new weighting function, then re-estimate union membership in year *t* using the new weights.

The resulting counterfactual mean informs us of how union membership in year *t* would differ from its observed value if the occupation shares within the population matched that of the base year (2002). Put differently, if the counterfactual mean of union membership in 2018 matches the observed mean of union membership in 2002, this implies that changes in RTI, occupations, and demographic characteristics have *directly* contributed to the changes in union membership. However, if the counterfactual mean for 2018 is closer to the observed 2018 mean rather than the 2002 mean, this suggests that demographic and occupational changes are unable to explain much of the decline in union membership.

In order for RBTC to directly affect union membership, this *must* occur through demographic or occupational changes, such as the reduction of high-RTI, middle-skilled industrial workers. Therefore, finding a compositional effect through DFL is a necessary but not sufficient condition for the argument that RBTC has a direct effect on union membership. To assess the indirect effect, we then analyse whether the proportion of change in union membership left unexplained by the decomposition has any strong relationship with automation exposure.

Third, we contextualise the quantitative findings with case studies of leading industrial trade unions in Germany, Finland and the United States. These countries are selected following the 'diverse case' strategy with a high range of variation on the outcome variable (union membership) (Seawright and Gerring 2008). The objective of the mixed-methods design is to provide a more detailed picture of the effects of RBTC on union membership than would be possible with a purely statistical analysis, also bearing in mind the difficulty of obtaining causal inferences when there is a legitimate argument to be made that the presence or strength of unions also affects firms' decisions to invest in automation (Bradley et al. 2017).

FINDINGS

Descriptive Findings

Figure 2. Scatterplot of changes in union membership (2002-2018) vs. initial levels in 2002, relative and percentage-point changes, by country.

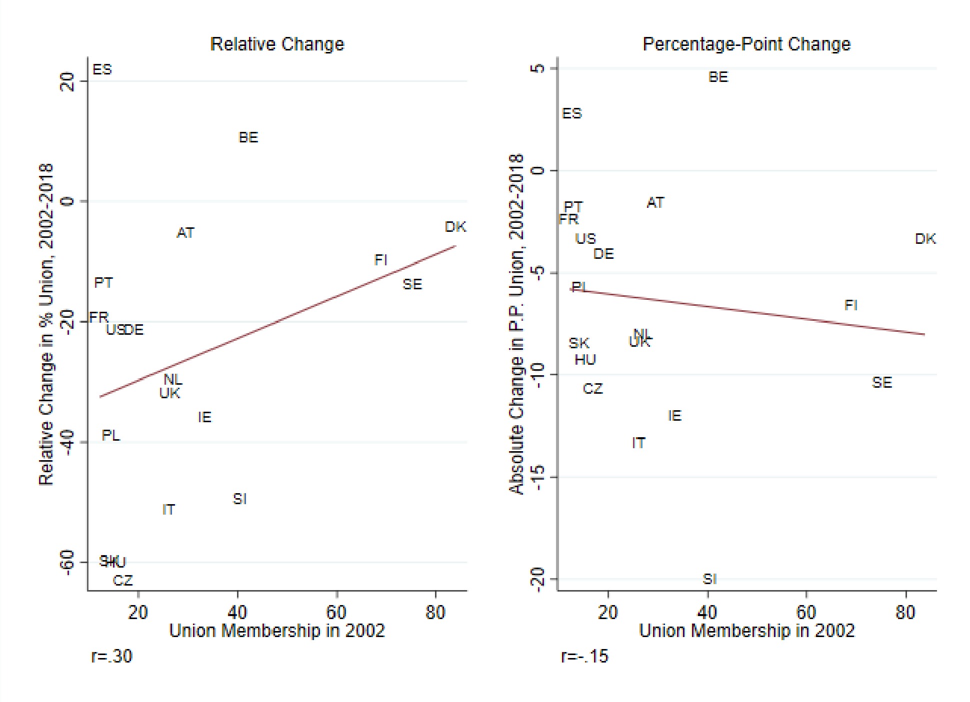
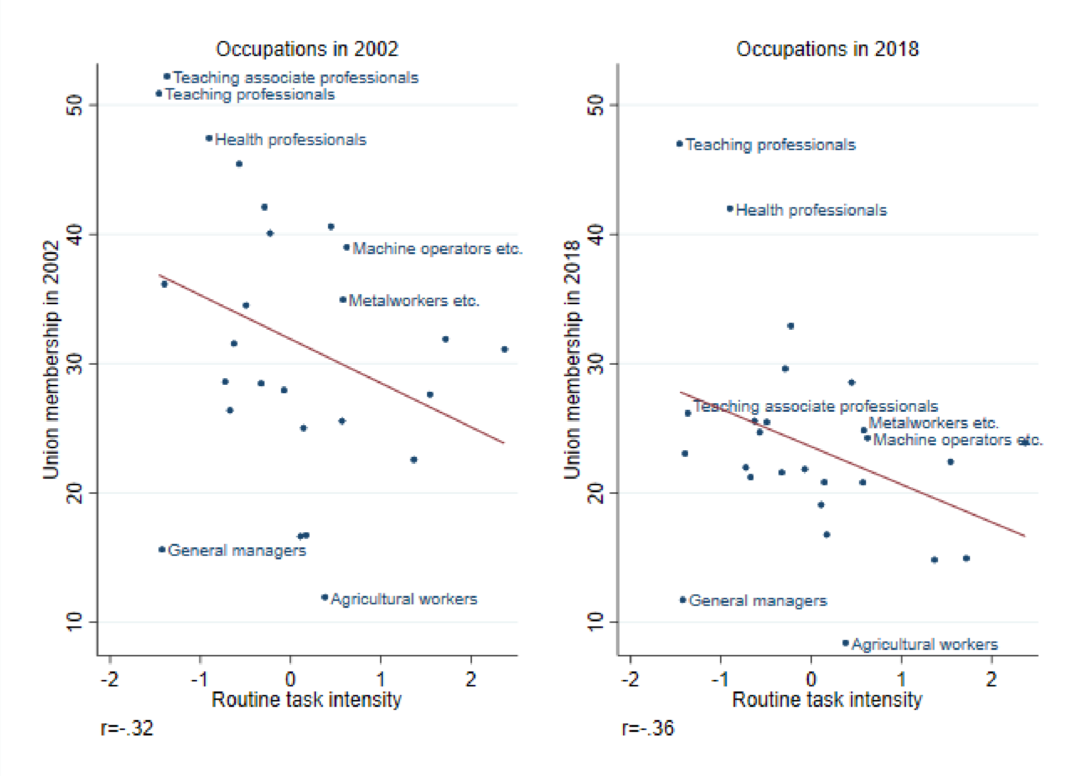


Figure 2 displays the change in union membership in 2018 compared to 2002, expressed in relative and absolute terms. This is plotted against the initial level of union membership in 2002. The left panel shows that countries with higher levels of union membership in 2002 see smaller relative declines in union membership through 2018, on average. Finland, Sweden and Denmark, all Ghent countries, stand out with the highest initial rates of union membership and the lowest relative decline. Belgium (the fourth Ghent country) and Spain are the only two countries where union membership has increased during the period of analysis, by approximately 10% or 4 percentage points.

The right panel expresses changes in percentage points rather than percent terms. The average fall in unionization is between 5 and 10 percentage points, weakly negatively correlated with starting levels. Overall, union decline 2002-2018 seems most pervasive in the Central-Eastern European countries, where declines in excess of 10 percentage points correspond to relative declines in excess of 40%. This indicates a risk of between-country polarization as Ghent countries with high union membership are better able to sustain the status quo whereas less unionized countries experience stronger declines.

Figure 3. Scatterplot of union membership vs. routine task intensity by ISCO 2-digit occupation, 2002 and 2018.



In years 2002 and 2018, were routine occupations more likely than other occupations to be unionized? This is an important precondition to the claim that RBTC has a direct effect on union membership. In Figure 3, we test this using data on union membership and routine task intensity of occupations at the ISCO 2-digit level. The results suggest that occupations with high RTI, such as metal and associated trades workers and machine operators, were on average less likely to be unionized than non-routine occupations in both 2002 and 2018. The highest likelihood of unionization is observed for low-RTI categories such as professionals in teaching, life sciences and health.

Moreover, the decline in union membership appears to be rather uniform across occupational categories. These descriptive results suggest it is unlikely that RBTC has a direct effect on union decline via the hypothesized mechanism of displacing high-RTI workers at a greater rate than low-RTI workers. In Appendix Figure A2, we find effectively no relationship between robot exposure and union decline within the manufacturing sector (r=-.01). This again counts against the direct effect hypothesis, suggesting that if RBTC is to have a net effect on union membership, this must occur through more complex channels than mechanical changes to the number of workers in different sectors and occupations.

Estimation Results

Table 1. OLS estimates of effects of RBTC on union membership (2002-2018).

	(1)	(2)	(3)	(4)	(5)
			DV: Union member		
Robot exposure	-0.018		-0.011		-0.011
	(0.012)		(0.011)		(0.011)
Routine task intensity		-0.010*		0.004	0.004
		(0.005)		(0.003)	(0.003)
Trade exposure			-0.001***	-0.001**	-0.001***
			(0.000)	(0.000)	(0.000)
Sex: female			-0.013	-0.014	-0.014
			(0.011)	(0.011)	(0.011)
Age (ref: 25-44)					
18-24			-0.105***	-0.105***	-0.105***
			(0.021)	(0.021)	(0.021)
45-65			0.053***	0.053***	0.053***
			(0.008)	(0.008)	(0.008)
Education (ref: upper secondary)					
Lower secondary			-0.034***	-0.034***	-0.034***
			(0.007)	(0.007)	(0.007)
Tertiary			-0.019	-0.017	-0.017
			(0.017)	(0.017)	(0.017)
Sector (ref: manufacturing)					
Agriculture			-0.127***	-0.126***	-0.126***
			(0.027)	(0.027)	(0.027)
Construction			-0.084***	-0.082***	-0.082***
			(0.013)	(0.013)	(0.013)
Public administration			0.102***	0.102***	0.103***
			(0.026)	(0.026)	(0.026)
Research and education			0.119***	0.124***	0.124***
			(0.024)	(0.023)	(0.023)
Health and social work			0.051**	0.054**	0.054**
			(0.020)	(0.020)	(0.020)
Private sector			-0.081***	-0.080***	-0.079***
			(0.013)	(0.013)	(0.013)
Observations	1,542,785	1,541,681	1,538,775	1,537,671	1,537,671
R-squared	0.249	0.250	0.290	0.290	0.290

Notes: All models include country and year dummies with a total of 19 countries and 9 years. Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 1 presents the results of our multivariate analysis following Equation (2). Models 1 and 2 show the unconditional effects of our two measures of automation, robot exposure and routine task intensity, on union membership, while Models 3 to 5 add in the country- and individual-level controls. The models include country and year fixed effects.

Notably, the only statistically significant coefficient for any of our automation indicators on union membership is for routine task intensity in the baseline model 2 which does not include any control variables. Once demographic, political and economic control variables are included, the effect of routine task intensity flips signs to positive, but fails to reach conventional levels of statistical significance (models 4 and 5). Exposure to industrial robots is not a statistically significant predictor of union membership in any specification.

Figure 4. Results of DiNardo-Fortin-Lemieux decomposition into explained and unexplained components of change in union membership, 2018 relative to 2002.

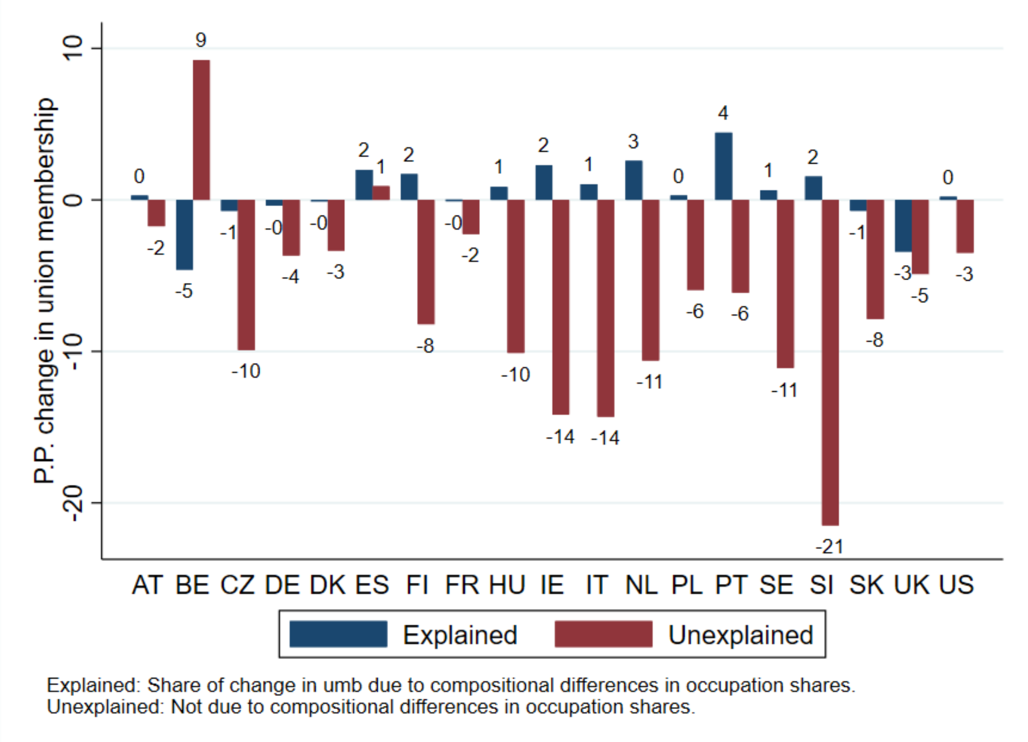


Figure 4 presents the results of our decomposition analysis, obtained by comparing the observed changes in union membership to counterfactual changes calculated applying Equation (3). The unexplained change in union membership is dominant, with some small exceptions. In Belgium and Spain (the only two countries in our sample without notable declines in union membership), the unexplained change is actually positive. In all other countries, it is negative, and generally strongly so. Importantly, the *explained* components tend to be positive – indicating that in the counterfactual scenario with no changes in worker demographics, routine task intensity, occupations or employment sectors from the baseline in 2002, union decline would have been *even stronger* than observed. In other words, changes in occupations and sectors of employment (i.e., the shift away from routine-intensive manufacturing) have generally reduced, rather than increased, the decline in union membership in recent decades. In Appendix Figure A3, we present decomposition results by year; the results again demonstrate that the recent transition to more non-routine and service-sector occupations has slowed down union decline, holding all else constant.

To summarize, our quantitative findings mostly rule out the 'direct effect' of RBTC on union membership. Exposure to automation does not appear to drive union decline either directly through changes in labour market participation, or indirectly through changes in unobserved characteristics such as individual preferences or attitudes. In Appendix I, we also demonstrate that the unexplained share of union decline is not strongly associated with either changes in industrial robots or changes in routine task intensity. The evidence thus suggests that RBTC by and large fails to account for the changes in union membership from 2002 to 2018, through either the *direct* or *indirect* pathways.

In the next section, we therefore turn our attention back to the political-institutional explanations of union decline, by looking at leading industrial unions in three countries with similarly high rates of automation exposure but very different levels of union membership – Germany, Finland, and the United States. This diverse case selection aims to highlight the underlying political and institutional differences in collective bargaining mechanisms which can plausibly account for the divergent outcomes in union membership.

Case Studies

Why should we expect country-specific political and institutional factors present to affect union membership more forcefully than routine-biased technological change? Following Garnero (2021), collective bargaining institutions contribute to unions' ability to shape bargaining outcomes, which in turn affects the added value and attractiveness of union membership. Thus, even if countries face similar exposure to automation, its effect on union membership may be mediated partially or fully through bargaining institutions.

Specifically, our cases suggest two path-dependent and mutually exclusive equilibria between automation and organized labour. On the one hand, when trade union membership is high, unions and works councils have sufficient leverage to bargain with employers over the introduction of industrial robots in a way that minimizes lay-offs and weakening of working conditions. This produces a highly credible benefit from unionization which helps sustain high levels of membership. On the other hand, when union membership and collective bargaining coverage is very low, employers are able to use labour-displacing technologies to pull down labour standards in a race-to-the-bottom fashion, further narrowing the scope for unions to bargain concessions and reducing their appeal.

Germany

The German system of industrial relations has a notable ’two-tier’ structure, where works councils have strong autonomy over company-level bargaining in the context of broad framework agreements negotiated by sectoral trade unions (Müller et al. 2018). Not all works council members are union affiliates, but unions naturally have an interest in having as many of their candidates elected as possible. The main industrial union, IG Metall, is also the largest union in the country and the manufacturing sector has bargaining coverage above the national average (Schulten and Bispinck 2018).

The question of RBTC has been salient in the manufacturing sector at least since the 1980s when industrial robots started to be introduced in Volkswagen plants (Haipeter 2020). Works councils at this time were carefully optimistic about automation but taking a rather passive stance to its roll-out, ’welcom[ing] the use of robot technologies as a contribution to improving competitiveness and as an opportunity to reduce restrictive working conditions at automated plants’ (Haipeter 2020: 246-7). The use of industrial robots today largely follows the same trajectory of incremental changes and improvements in the production process building on top of past technologies.

The industrial sector in Germany is particularly focused on car manufacturing, with the large automotive companies Volkswagen, Daimler and BMW among the largest employers in the country. This is despite the German automotive sector having the highest intensity of industrial robots anywhere in Europe (Dauth et al. 2021). According to industry experts, digitalization and automation throughout the value chain is essential for remaining globally competitive and keeping high-value-added manufacturing in Germany, as communicated in the ’Industry 4.0’ vision (Lefeuvre and Guga 2019). However, industrial robots have fundamentally changed the character of industry-sector employment by displacing routine, blue-collar manual work and creating new, non-routine occupations requiring technical skills such as IT and data analytics (Strötzel and Brunkhorst 2019). Robots therefore directly contribute to skills polarization: even if they allow the ’re-shoring’ of factories from low-cost countries in the Global South or Central and Eastern Europe, factories in Western Europe overwhelmingly employ high-skilled workers such as engineers, researchers and experienced machine operators to justify the economic cost of operating in a high-labour-cost environment (Krzywdzinski 2017, Krenz et al. 2021).

Given this set of conflicting views on the employment effects of industrial robots, IG Metall has traditionally followed the other industrial stakeholders in viewing RBTC as an integral part of German manufacturing rather than a disruptive threat. Union policies towards RBTC involve supporting works councils to negotiate more comprehensive workplace agreements (Haipeter 2020). Since the implementation of new technologies falls outside the scope of co-determination, employers hold an asymmetrical amount of power on this issue. This is reflected in the general perception that working conditions have become worse, not better, with automation (Haipeter 2020: 253). Concerns raised most frequently by employees include high physical and mental workloads, inadequate training for new technologies, the use of several mutually incompatible computer systems, and the intensification of working hours as companies operate on reduced staff or optimized scheduling.

According to industry actors, the German automotive sector faces three medium-term threats: the phase-out of internal combustion engines, the expansion of the sharing economy to personal mobility, and automation. However, only the first two present existential challenges to the industry, to the extent that they drastically cut back the demand for personal passenger vehicles or shift that demand towards electric vehicles whose production is dominated by Asian manufacturers (Strötzel and Brunkhorst 2019). The number of jobs potentially lost to automation pales in comparison to the paradigm shift to electric vehicles, since their manufacturing requires substantially fewer components and shorter supply chains than combustion-engine vehicles. IG Metall has led the union response at the European level, calling for policy coordination to ensure that the continent does not fall behind in electric vehicle production. In brief, manufacturing employment in Germany depends more than ever on being on the correct side of technological change, and unions are keenly aware of this. Thus, one could argue that in the long run RBTC is necessary for maintaining membership in industrial unions rather than undermining it.

Finland

Social partners in Finland emphasize the necessity of automation, digitalization and RBTC to maintain and re-shore employment in high-value-added manufacturing. The largest industrial union Teollisuusliitto emphasizes that the export-oriented metalworking and manufacturing industries have effectively merged into a single sector called *technological industries (teknologiateollisuus)* (Pyöriä et al. 2020). This sector is characterized by increasing coordination between traditional refining and manufacturing on the one hand, and electronic and communication technologies on the other. Comparative advantage is sought in the manufacturing of complex and technologically advanced products such as electric vehicles and ocean-going ships. The share of industry-sector workers with upper secondary and tertiary education has increased dramatically over the last 40 years, with jobs moving from the factory floor towards business functions, sales and customer service, and process management and analytics (Pyöriä et al. 2020).

Finnish employer associations seem to be generally more favourable towards industrial robots than trade unions, as their roll-out has been associated with labour market dualization. The existing system of vocational education and apprenticeship programmes has failed to keep up with RBTC, resulting in skills mismatches between graduates and vacancies in the technological industries (Jokinen 2020). Additional digital divides are emerging among both employers and employees. The increasing share of analytical and supervisory tasks even in lower-level occupations requires both employees with adaptability and willingness to take on additional responsibilities, and a management culture compatible with a high level of employee self-direction and independent problem-solving. The firms that most successfully adapt to RBTC tend to have healthy labour-management relations, open communications with the workforce, and a shared vision of technology in the workplace (Jokinen 2020).

The evidence suggests that union representation at workplace, sectoral, and national levels is an asset during the process of RBTC, as it facilitates the negotiation of mutually beneficial agreements. However, the 'Nordic model' of strongly centralized and coordinated bargaining is not immune from the global trends of labour flexibilization and recommodification (Høgedahl and Kongshøj 2017; Wuokko et al. 2020). In the early 2020s, major employers in the forest and technology industries have actively sought to break free from the mould of tripartite corporatism, sectoral bargaining and automatic collective agreement extensions, stepping up the intensity of the pursuit for decentralization that has been a central employer-side objective for three decades (Bergholm and Sippola 2022). In the 2021/22 rounds of collective bargaining, the technology-sector employers and unions by and large preserved industrial peace during the negotiations of inaugural firm-level collective agreements, whereas in the forest sector the Paperworkers' Union with the support of their confederation SAK and the unions of electrical, industrial, road and rail transport workers engaged in an historically long, four-month strike vis-à-vis major forest firm UPM over the question of decentralising collective agreements down to the level of individual production units (Yle 2022).

With high labour costs and a small, highly educated population, Finland is arguably more dependent on RBTC to uphold competitive manufacturing than other European countries. As evidenced by the mutually agreed rebranding of manufacturing to technological industries, both employers and unions view RBTC as key to competitiveness and long-term employability, even if they disagree on the details. Similar to Germany, the social partners take a ‘pragmatic’ approach to automation, viewing it as a bargaining point in the rapidly changing industrial sector rather than an existential threat *per se* (Müller et al. 2018, Bergholm and Sippola 2022). This also implies that RBTC in its own right is not a driver of union decline. As the prolonged industrial action at UPM factories indicates, employer agency and the relative power of management vis-à-vis labour are central forces in reshaping union membership.

United States

Similarly to Germany, the effects of RBTC on organized labour in the US centre upon car manufacturing. The Fordist model of production, which involved the standardisation of work along mechanized production lines, was an example of automation pre-dating the concept of RBTC. From its widespread adoption in the 1920s to the 1950s, technological change in the manufacturing sector almost exclusively focused on improving the efficiency, flexibility and productivity of machines working alongside semi-skilled operators, machinists and other human inputs, with the model coming to be known as ‘Detroit automation’ (Hounshell 2000). From a labour perspective, the main asset of Detroit automation was the strong complementarity that existed between technology and blue-collar, semi-skilled labour. This empowered industrial workers to unionize and bargain for better wages and working conditions (Iversen and Soskice 2015: 194). Industrial unions such as the United Auto Workers (UAW) consequently gained substantive membership numbers and policy influence. This highlights an overarching point emerging from all of our case studies: automation *per se* does not have a direct and consistent effect on union membership, but what matters is the political-institutional context in which automation is introduced. As the experience of UAW in the post-Fordist era demonstrates, skill-complementary automation has a very different impact on unionization than automation which accelerates labour market polarization.

In the post-war decades, UAW’s view on automation was not necessarily benign, but at least cautiously optimistic, reflected in the visionary statements of union president Walter Reuther (Steigerwald 2010). Reuther’s thinking shared many elements with John Maynard Keynes’ vision of a ’post-industrial’ society, where automation would liberate blue-collar workers from the ’drudgery’ of the production line, allowing them to ’cultivate the higher ends of life’ or pursue more complex, high-skilled or creative work better fit for human faculties (Steigerwald 2010: 431-4). Nonetheless, RBTC came to hit manufacturing employment hard – from the mid-1960s to 2020, employment in the US manufacturing sector declined by roughly 25% (or 5 million workers), and national union density by a full 67% (or 20 percentage points) (OECD and AIAS 2021).

The dilemma of Walter Reuther, where RBTC increased human productivity and workplace safety at the cost of falling blue-collar employment and union membership, continues to haunt UAW to this day. Union executives interviewed by Cody (2015) acknowledge that employment in the automotive sector depends on industrial robots and other productivity-enhancing technologies. Even if very few workers are employed in the highly automated factories, this is preferable to the alternative of losing manufacturing altogether. Likewise, union priorities in the face of RBTC are twofold. On the one hand, UAW successfully bargained for employment guarantees at Ford and General Motors during the 1980s, ensuring that workers whose jobs were lost to automation would be retrained or given other jobs within the firm (Cody 2015: 18). On the other hand, the union has consistently advocated for active labour market policies such as relocation incentives, higher education and retraining, and early retirement for high-RTI workers whose occupations would otherwise be lost to automation (Steigerwald 2010: 441-5). However, the ability of UAW to follow through with its bargaining demands at the firm, state and federal levels has dramatically declined since the 1960s in tandem with the country-wide fall in union membership. To the extent that automation and RBTC have remained substantive bargaining points over the past half-century, with the policy prescriptions of the UAW remaining notably constant, it then begs the question of what other factors have changed that can plausibly account for the fall in union membership.

As further evidence of the difficulty in assigning a direct role for RBTC in driving US union decline, Milkman (2013) points out that union membership has fallen precipitously across *all* private sector occupations, not only those with exposure to trade or automation. For her, the main explanation is political, not technological: specifically, the ’broader logic of neoliberal economic restructuring that has transformed the United States since the 1970s’ (Milkman 2013: 652). This view is shared by Berg (2019), who argues that technology on its own is neutral, but designing and applying technologies in ways that displace, disadvantage or commodify labour is a political choice.

Present-day debates over RBTC unfold in a context of historically weak unionization. The debate, however, is remarkably similar to that in the 1960s, including the dichotomy of utopian and dystopian visions, the concerns over mass unemployment overriding questions regarding job quality, and the range of policy proposals including 'reduced working hours [and] retraining, union negotiations around technological implementation, social safety nets and ensuring that a variety of people [have] access to the new technologies' (Cherry 2020: 13). To the extent that automation is necessary for maintaining or re-shoring production to the US, the best outcomes for labour arise in firms where labour and management express a shared commitment to 'mitigate the worker displacement effects of task displacement' (Pietrykowski and Folster 2019: 369). Clearly, the effects of RBTC on union membership are mediated through the political attitude and power of management. A case in point is the recent UAW-IG Metall joint effort to unionize the US-based plants of German car manufacturers, which failed largely due to the strong 'union-busting' efforts of local company executives (Fichter 2018). Whether RBTC becomes a catalyst for industry restructuring, as IG Metall seeks to accomplish in Germany, or a mechanism for undermining the bargaining power of labour, as is happening to UAW in the US South, depends on the balance of power between labour and capital.

CONCLUSION

The effects of automation and routine-biased technological change on union membership are not a new topic of interest. In fact, this debate is one of the oldest in industrial relations. Chapter 15 of Marx's *Capital* elaborates in great detail on the effects of labour-saving machinery on the livelihoods of manufacturing workers, the changing employment patterns of men, women and children, and the ability of wage-labourers to organize and collectively demand regulations and limits on the exploitation of workers in mechanized factories (Marx 1887 [2015]). Our contribution aimed at comparing the effects of routine-biased technological change to the political-institutional determinants of union decline in post-industrial democracies, bringing together the dominant arguments in economics and political economy.

Using two estimation strategies and two indicators of automation, we found no statistically significant effect of automation exposure on union membership in European countries from 2002 to 2018. Instead, had the composition of the labour force remained constant in terms of routine task intensity, occupations, employment sectors and demographics, union membership would on average have declined by 0.9 percentage points *more* than observed in 2018. In other words, the recent expansion of the service economy, particularly in terms of female public sector employment, has done more good than harm for overall union membership (Bergholm and Sippola 2022).

The findings from our statistical analysis were consistent with case studies of leading industrial unions in Germany, Finland and the United States. In all three countries, social partners agreed on the necessity of RBTC for safeguarding competitiveness and employment in manufacturing. However, only in the US have employers used automation to directly undermine union membership. In the German and Finnish bargaining systems, union members have a greater say in the implementation of industrial robots. The persistent differences in union power and membership between the three countries in the post-industrial era suggests that organized labour institutions are more than passive onlookers to RBTC – rather, they actively use their agency to pursue the best possible outcomes for labour in changing labour markets.

The fact that German works councils and Finnish collective agreements have withstood employer opposition to a much greater degree than US trade unions, which have to fight each successive workplace election from a standing start and against explicit union-busting campaigns, suggests that the power (or weakness) of organized labour can be self-perpetuating. Varieties of capitalism theories elaborate on the distinction between coordinated and liberal market economies, where strong unions and robust bargaining institutions in the former group are complementary to long-term investments in technological and human capital, whereas weak unions and laissez-faire labour markets in the latter support firms' decisions to invest in labour-displacing technologies and flexible employment relationships (Iversen and Soskice 2015). This substantive political-institutional difference has been brought up as a plausible explanation to the conflicting estimates suggesting that industrial robots have on average destroyed jobs in the United States, but not in European countries with equivalent or even stronger intensity of robot use such as Germany (Dauth et al. 2021).

To conclude, we find no evidence that the increasing use of industrial robots has reduced union membership in European countries from 2002 to 2018. To the extent that routine-biased technological change has reduced high-RTI employment in the manufacturing sector, it has also contributed to the increase in non-routine occupations in manufacturing, public and private service sectors. Furthermore, we find that in countries at the forefront of RBTC such as Finland, the majority of union members are employed in public sector services rather than manufacturing. From the worker's perspective, the primary determinant for the decision to unionize is not a theoretical measure such as the labour-capital ratio or exposure to industrial robots – but the rather pragmatic question of whether the workplace has a union with sufficient power to fight for better earnings or working conditions. The answer to this question depends on the balance of power between capital and labour, or in other words, on the political and institutional power of labour.

REFERENCES

Acemoglu, D., Aghion, P., & Violante, G. L. (2001). Deunionization, Technical Change and Inequality. Paper presented at the Carnegie-Rochester Conference Series on Public Policy, North-Holland.

Acemoglu, D., & Autor, D. (2011). Skills, Tasks and Technologies: Implications for Employment & Earnings. In *Handbook of Labor Economics*, Volume 4b.

Acemoglu, D., & Restrepo, P. (2019). Automation and New Tasks: How Technology Displaces and Reinstates Labor. *Journal of Economic Perspectives*, 33(2), 3-30.

Acemoglu, D., & Restrepo, P. (2020). Robots and Jobs: Evidence from US Labor Markets. *Journal of Political Economy*, 128(6), 2188-2244.

Anttila, A.-H. (2021). Enemmän kuin numero tilastoissa: Teollisuusliiton jäsentutkimus 2020 [More than a Statistic: Industrial Union Member Survey 2020]. Helsinki: Industrial Union of Finland.

Autor, D. H., & Dorn, D. (2013). The Growth of Low-Skill Service Jobs and the Polarization of the US Labor Market. *American Economic Review*, 103(5), 1553-1597.

Autor, D. H., Dorn, D., & Hanson, G. H. (2015). Untangling Trade and Technology: Evidence from Local Labour Markets. *The Economic Journal*, 125, 621-646.

Autor, D. H., Levy, F., & Murnane, R. J. (2003). The Skill Content of Recent Technological Change: An Empirical Exploration. *The Quarterly Journal of Economics*, 118(4), 1279-1333.

Becher, M., & Pontusson, J. (2011). Whose Interests Do Unions Represent? Unionization by Income in Western Europe. In Brady, D. (ed.) *Comparing European Workers Part B: Policies and Institutions*. Bingley: Emerald, pp. 181-211.

Berg, J. (2019). Protecting Workers in the Digital Age: Technology, Outsourcing, and the Growing Precariousness of Work. *Comparative Labor Law & Policy Journal*, 41(1), 69-94.

Bergholm, T., & Sippola, M. (2022). The Restructuring of Finnish Trade Unions – the Growing Importance of Women. *Nordic Journal of Working Life Studies*, 12(S8).

Bertolini, A., & Dukes, R. (2021). Trade Unions and Platform Workers in the UK: Worker Representation in the Shadow of the Law. *Industrial Law Journal*, 50(4), 662-688.

Blanas, S., Gancia, G., & Lee, S. Y. (2019). Who Is Afraid of Machines? *Economic Policy*, 34(100), 627-690.

Bradley, D., Kim, I., & Tian, X. (2017). Do Unions Affect Innovation? *Management Science*, 63(7), 2251-2271.

Brady, D., Baker, R. S., & Finnigan, R. (2013). When Unionization Disappears: State-Level Unionization and Working Poverty in the United States. *American Sociological Review*, 78(5), 872-896.

Chauvel, L., & Schröder, M. (2017). A Prey-Predator Model of Trade Union Density and Inequality in 12 Advanced Capitalisms over Long Periods. *Kyklos*, 70(1), 3-26.

Checchi, D., & Visser, J. (2005). Pattern Persistence in European Trade Union Density: A longitudinal analysis 1950-1996. *European Sociological Review,* 21(1), 1-21.

Cherry, M. A. (2020). Back to the Future: A Continuity of Dialogue on Work and Technology at the ILO. *International Labour Review,* 159(1), 1-23.

Cody, J. (2015). How Labor Manages Productivity Advances and Crisis Response: A Comparative Study of Automotive Manufacturing in Germany and the US. Global Labour University Working Paper no. 32. Geneva: International Labour Organization.

Dauth, W., Findeisen, S., Südekum, J., & Wössner, N. (2021). The Adjustment of Labor Markets to Robots. *Journal of the European Economic Association,* 19(6), pp. 3104-53.

Denice, P., & Rosenfeld, J. (2018). Unions and Nonunion Pay in the United States, 1977-2015. *Sociological Science*, 5, 541-561.

DiNardo, J., Fortin, N. M., & Lemieux, T. (1996). Labor Market Institutions and the Distribution of Wages, 1973-1992: A Semiparametric Approach. *Econometrica*, 64(5), 1001-1044.

Ebbinghaus, B., & Visser, J. (1999). When Institutions Matter: Union Growth and Decline in Western Europe, 1950-1995. *European Sociological Review*, 15(2), 135-158.

Fichter, M. (2018). Building Union Power Across Borders: The Transnational Partnership Initiative of IG Metall and the UAW. *Global Labour Journal*, 9(2), 182-198.

Frey, C. B., & Osborne, M. A. (2017). The Future of Employment: How Susceptible are Jobs to Computerisation? *Technological Forecasting and Social Change*, 114, 254-280.

Garnero, A. (2021). The Impact of Collective Bargaining on Employment and Wage Inequality: Evidence from a New Taxonomy of Bargaining Systems. *European Journal of Industrial Relations*, 27(2), 185-202.

Goos, M., Manning, A., & Salomons, A. (2014). Explaining Job Polarization: Routine-Biased Technological Change and Offshoring. *American Economic Review*, 104(8), 2509-2526.

Graetz, G., & Michaels, G. (2018). Robots at Work. *The Review of Economics and Statistics*, 100(5), 753-768.

Haipeter, T. (2020). Digitalisation, Unions and Participation: The German Case of "Industry 4.0". *Industrial Relations Journal,* 51(3), 242-260.

Haslberger, M. (2021). Rethinking the measurement of occupational task content. *The Economic and Labour Relations Review*.

Høgedahl, L., & Kongshøj, K. (2017). New trajectories of unionization in the Nordic Ghent countries: Changing labour market and welfare institutions. *European Journal of Industrial Relations*, 23(4), 365-380.

Hounshell, D. A. (2000). Automation, Transfer Machinery, and Mass Production in the U.S. Automobile Industry in the Post-World War II Era. *Enterprise & Society, 1*(1), 100-138.

Huber, E., & Stephens, J. D. (2001). *Development and Crisis of the Welfare State: Parties and Policies in Global Markets*. Chicago: University of Chicago Press.

Ibsen, C. L., & Tapia, M. (2017). Trade union revitalisation: Where are we now? Where to next? *Journal of Industrial Relations,* 59(2), 170-191.

Ibsen, C. L., Toubøl, J., & Jensen, D. S. (2017). Social Customs and Trade Union Membership: A Multi-Level Analysis of Workplace Union Density Using Micro-Data. *European Sociological Review, 33*(4), 504-517.

IFR (International Federation of Robotics). (2020). *World Robotics: Industrial Robots.* Frankfurt: IFR Statistical Department.

Im, Z. J., & Komp-Leukkunen, K. (2021). Automation and Public Support for Workfare. *Journal of European Social Policy*, 41(4), 457-472.

Iversen, T., & Soskice, D. (2015). Democratic Limits to Redistribution: Inclusionary versus Exclusionary Coalitions in the Knowledge Economy. *World Politics*, 67(2), 185-225.

Jokinen, E. (2020). Kilpailuetua ja yhteistä oppimista: Mitä teollisuusaloilla ajatellaan osaamisesta? [Competitive Advantage and Mutual Learning: What Do the Industrial Sectors Think About Skills?]. In S. Ojala & P. Pyöriä (Eds.), *Pirstoutuvatko työurat? Teollisuusalat talouden ja teknologian murroksissa.* Tampere: Tampere University Press.

Kelly, J. (2015). Trade union membership and power in comparative perspective. *The Economic and Labour Relations Review*, 26(4), 526-544.

Keune, M., & Pedaci, M. (2020). Trade Union Strategies Against Precarious Work: Common Trends and Sectoral Divergence in the EU. *European Journal of Industrial Relations*, 26(2), 139-155.

Korpi, W. (1983). *The Democratic Class Struggle.* London: Routledge & Kegan Paul.

Korpi, W. (2006). Power Resources and Employer-Centered Approaches in Explanations of Welfare States and Varieties of Capitalism: Protagonists, Consenters, and Antagonists. *World Politics*, 58(2), 167-206.

Krenz, A., Prettner, K., & Strulik, H. (2021). Robots, Reshoring, and the Lot of Low-Skilled Workers. *European Economic Review*, 136.

Krzywdzinski, M. (2017). Automation, Skill Requirements and Labour-Use Strategies: High-Wage and Low-Wage Approaches to High-Tech Manufacturing in the Automotive Industry. *New Technology, Work and Employment,* 32(3), 247-267.

Lefeuvre, A.-G., & Guga, Ș. (2019). Troubled Waters Ahead: What's Next for the European Automobile Industry and Jobs? In B. Galgóczi (Ed.), *Towards a Just Transition: Coal, Cars and the World of Work*. Brussels: European Trade Union Institute.

Mahutga, M. C., Curran, M., & Roberts, A. (2018). Job Tasks and the Comparative Structure of Income and Employment: Routine Task Intensity and Offshorability for the LIS*. *International Journal of Comparative Sociology,* 59(2), 81-109.

Marx, K. (1887 [2015]). *Capital, Volume I*. Retrieved from: https://www.marxists.org/archive/marx/works/download/pdf/Capital-Volume-I.pdf.

Meyer, B. (2019). Financialization, Technological Change, and Trade Union Decline. *Socio-Economic Review*, 17(3), 477-502.

Meyer, B., & Biegert, T. (2019). The Conditional Effect of Technological Change on Collective Bargaining Coverage. *Research & Politics*, 6(1).

Milkman, R. (2013). Back to the Future? US Labour in the New Gilded Age. *British Journal of Industrial Relations,* 51(4), 645-665.

Müller, T., Dølvik, J. E., Ibsen, C., & Schulten, T. (2018). The Manufacturing Sector: Still an Anchor for Pattern Bargaining Within and Across Countries? *European Journal of Industrial Relations,* 24(4), 357-372.

OECD, & AIAS. (2021). *Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts*. Retrieved from: www.oecd.org/employment/ictwss-database.htm

Ost, D. (2009). The End of Communism: Trade Unions in Eastern Europe's Future. *East European Politics and Societies,* 23(1), 13-33.

Palm, J. (2017). The declining influence of class and ideology in union membership: Consistent but divergent trends among Swedish employees. *Economic and Industrial Democracy*, 41(2), 351-371.

Pietrykowski, B., & Folster, M. (2019). Boundary Crossings: Collaborative Robots and Human Workers. *Ethnographic Praxis in Industry Conference Proceedings,* 362-379.

Pyöriä, P., Jokinen, E., Järvinen, K.-M., & Lipiäinen, L. (2020). ’Teknologia, metsä ja kemia: Suomen teollisuus viime vuosikymmenillä [Technology, Forest and Chemistry: Finnish Industry Over the Last Decades]. In S. Ojala & P. Pyöriä (Eds.), *Pirstoutuvatko työurat? Teollisuusalat talouden ja teknologian murroksissa*. Tampere: Tampere University Press.

Schulten, T., & Bispinck, R. (2018). Varieties of Decentralisation in German Collective Bargaining. In S. Leonardi & R. Pedersini (Eds.), *Multi-Employer Bargaining Under Pressure: Decentralisation Trends in Five European Countries*. Brussels: European Trade Union Institute.

Seawright, J., & Gerring, J. (2008). Case Selection Techniques in Case Study Research: A Menu of Qualitative and Quantitative Options. *Political Science Quarterly*, 61(2), 294-308.

Standing, G. (2013). *The Precariat: The New Dangerous Class*. London: Bloomsbury.

Steigerwald, D. (2010). Walter Reuther, the UAW, and the dilemmas of automation. *Labor History*, 51(3), 429-453.

Strötzel, M., & Brunkhorst, C. (2019). Managing the Transformation of the German Automotive Industry. In B. Galgóczi (Ed.), *Towards a Just Transition: Coal, Cars and the World of Work.* Brussels: European Trade Union Institute.

Visser, J. (2012). The Rise and Fall of Industrial Unionism. *Transfer: European Review of Labour and Research*, 18(2), 129-141.

Western, B., & Rosenfeld, J. (2011). Unions, Norms, and the Rise in U.S. Wage Inequality. *American Sociological Review,* 76(4), 513-537.

Wuokko, M., Jensen-Eriksen, N., Tala, H., Kuorelahti, E., & Sahari, A. (2020). *Loputtomat kihlajaiset: Yritykset ja kolmikantakorporatismi Suomessa 1940-2020* [The Endless Engagement Party: Businesses and Tripartite Corporatism in Finland 1940-2020]. Helsinki: Siltala.

Yle. (2022). UPM strike ends as union, employer accept proposal from mediator. *Yle News* 22.4.2022. Retrieved 02.05.2022 from https://yle.fi/news/3-12414126

APPENDIX I

Online Appendix for "Blame the Robots? Routine-Biased Technological Change and the Recent Decline of Union Membership in Europe and the United States"

Figure A1: Scatterplot of unexplained decline in union membership (share not explained by changing composition) vs. robot exposure and RTI, 2018 relative to 2002.

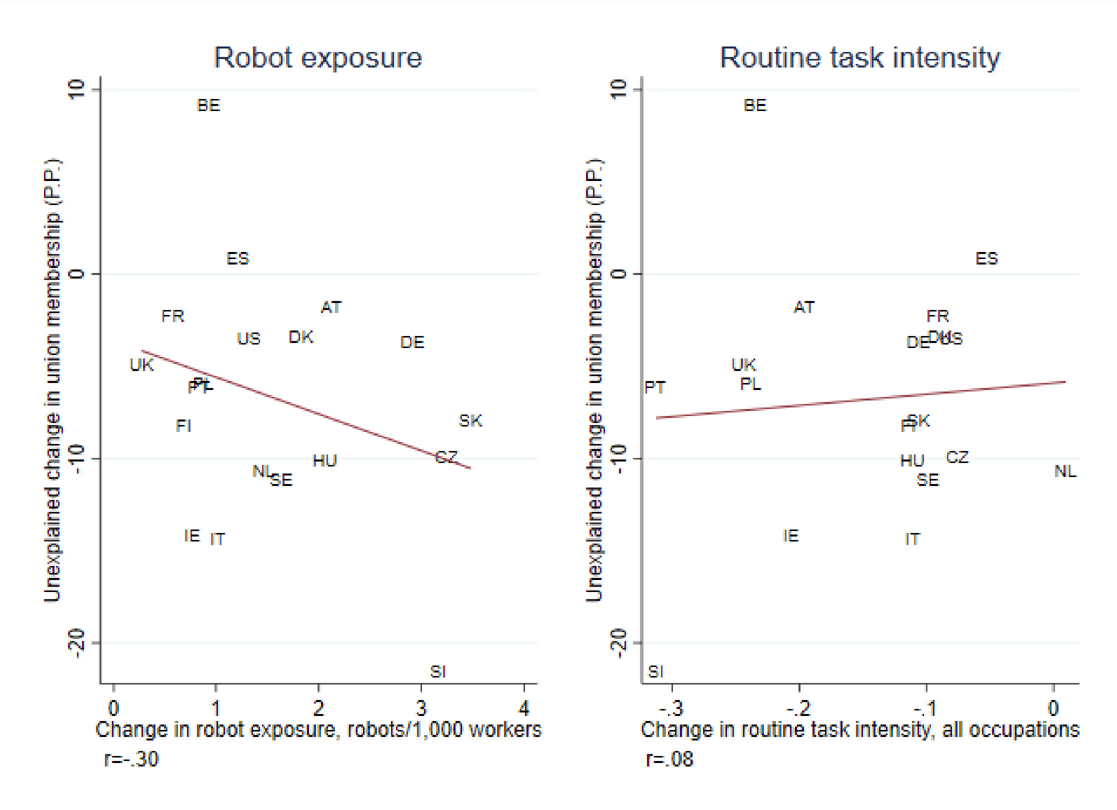


Figure A2: Scatterplot of absolute change in union membership vs. change in exposure to industrial robots (2002 to 2018), country-level and manufacturing sector.

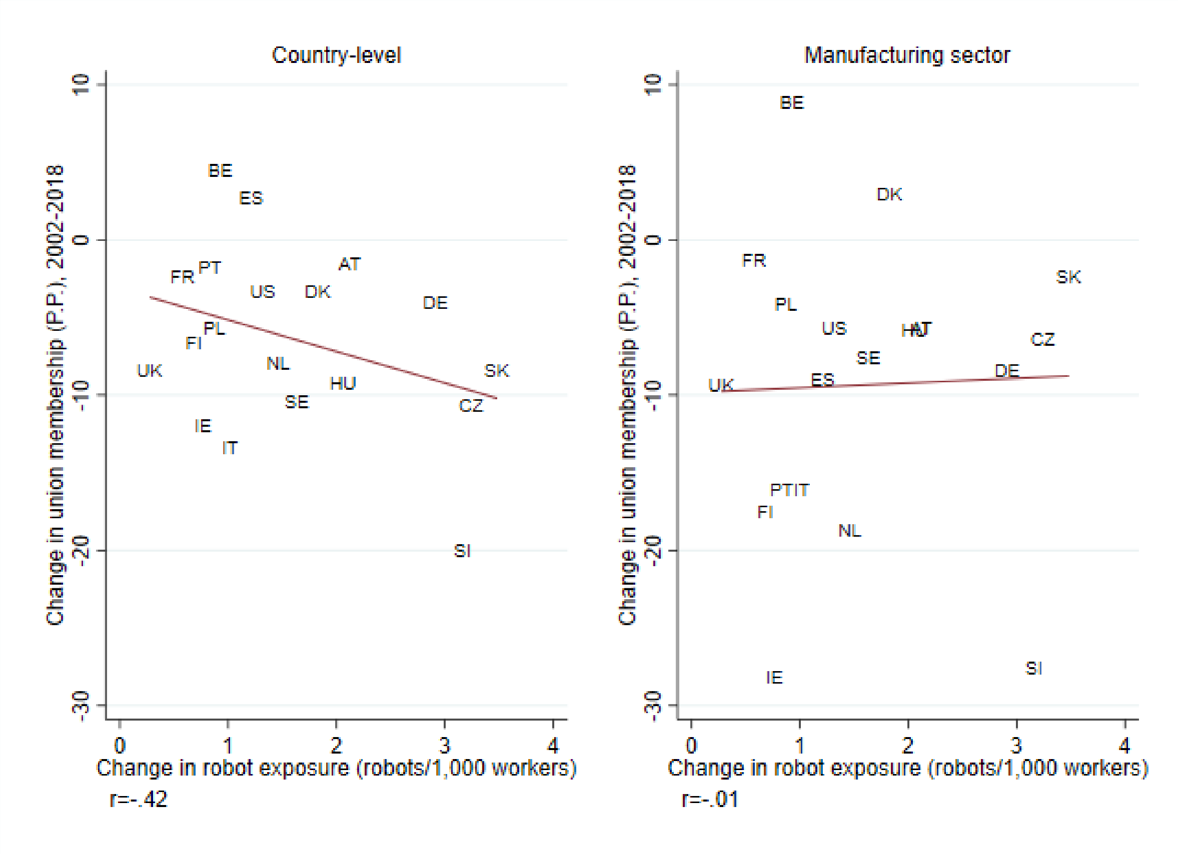


Figure A3: Results of DiNardo-Fortin-Lemieux decomposition into explained and unexplained components of change in union membership relative to 2002, country averages by year.

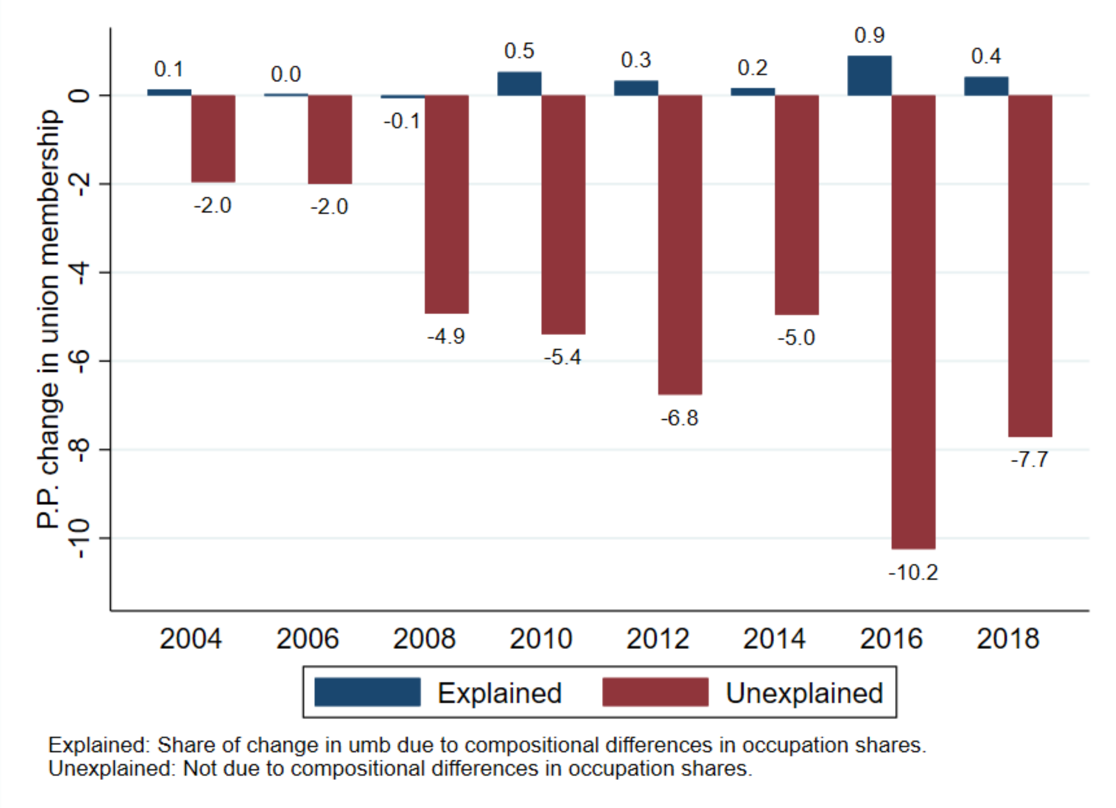


Table A1. Descriptive Statistics for Key Variables. Sources: own calculations from ESS, US-CPS, IFR, LIS and CPDS.

Country	Years	Survey waves	Union membership		Robot exposure		Routine task intensity		Trade exposure	
		n	mean	sd	mean	sd	mean	sd	mean	sd
AT	2002-18	6	27.6	2.49	1.82	0.87	0.17	0.12	98.1	7.9
BE	2002-18	9	46.0	1.82	1.83	0.34	-0.13	0.10	153.0	10.7
CZ	2002-18	8	9.3	4.26	1.42	1.14	0.06	0.09	132.4	22.5
DE	2002-18	9	16.1	1.76	4.08	0.92	-0.05	0.05	78.9	9.4
DK	2002-18	8	81.6	1.68	1.52	0.59	-0.21	0.07	96.9	9.3
ES	2002-18	9	13.4	1.55	1.98	0.35	-0.09	0.10	59.0	5.2
FI	2002-18	9	67.4	2.11	2.05	0.24	-0.23	0.06	76.2	5.6
FR	2002-18	9	10.8	0.90	1.37	0.17	-0.09	0.05	57.7	4.1
HU	2002-18	9	9.9	4.48	0.69	0.71	0.08	0.09	151.9	18.6
IE	2002-18	9	26.9	4.61	0.34	0.27	-0.16	0.07	182.9	29.2
IT	2002-18	4	17.8	6.92	2.73	0.43	0.01	0.09	54.9	5.1
NL	2002-18	9	22.9	2.75	0.91	0.52	-0.19	0.05	136.5	15.9
PL	2002-18	9	10.2	2.04	0.32	0.30	-0.10	0.12	84.8	14.4
PT	2002-18	9	10.8	3.00	0.57	0.27	0.09	0.14	72.9	8.2
SE	2002-18	9	69.4	4.47	2.37	0.55	-0.25	0.06	84.5	5.0
SI	2002-18	9	29.2	7.62	1.50	1.11	-0.02	0.10	133.7	18.0
SK	2004-18	6	11.2	3.05	1.10	1.32	-0.01	0.07	164.7	17.5
UK	2002-18	9	22.7	2.54	0.61	0.09	-0.12	0.09	57.0	4.2
US	2002-18	9	13.7	1.09	1.34	0.43	0.00	0.04	27.3	2.8

Table A1 continued

Country	Years	Survey waves	Female share		Age group (3 categories)		Education (3 categories)	
		n	mean	sd	mean	sd	mean	sd
AT	2002-18	6	0.47	0.01	1.31	0.05	2.11	0.11
BE	2002-18	9	0.47	0.03	1.32	0.05	2.17	0.09
CZ	2002-18	8	0.45	0.02	1.39	0.06	2.13	0.06
DE	2002-18	9	0.46	0.02	1.39	0.05	2.16	0.03
DK	2002-18	8	0.47	0.01	1.36	0.03	2.17	0.05
ES	2002-18	9	0.45	0.03	1.31	0.10	1.93	0.07
FI	2002-18	9	0.48	0.00	1.40	0.03	2.27	0.09
FR	2002-18	9	0.48	0.02	1.34	0.04	2.11	0.11
HU	2002-18	9	0.47	0.01	1.31	0.05	2.08	0.05
IE	2002-18	9	0.44	0.02	1.27	0.06	2.25	0.14
IT	2002-18	4	0.42	0.02	1.41	0.07	1.79	0.11
NL	2002-18	9	0.47	0.02	1.33	0.05	2.10	0.08
PL	2002-18	9	0.45	0.01	1.26	0.04	2.04	0.06
PT	2002-18	9	0.49	0.02	1.32	0.07	1.57	0.18
SE	2002-18	9	0.48	0.01	1.39	0.02	2.23	0.08
SI	2002-18	9	0.45	0.02	1.31	0.07	2.17	0.09
SK	2004-18	6	0.45	0.01	1.31	0.05	2.13	0.05
UK	2002-18	9	0.47	0.01	1.29	0.03	2.13	0.18
US	2002-18	9	0.47	0.00	1.33	0.03	1.94	0.06