OECD Social, Employment and Migration Working Papers
No. 228

Automation and occupational wage trends

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https://dx.doi.org/10.1787/596b32ce-en

OECD

Organisation for Economic Co-operation and Development

DELSA/ELSA/WD/SEM(2019)8

For Official Use **English - Or. English**

16 May 2019

DIRECTORATE FOR EMPLOYMENT, LABOUR AND SOCIAL AFFAIRS
EMPLOYMENT, LABOUR AND SOCIAL AFFAIRS COMMITTEE

Automation and Occupational Wage Trends

What Role for Unions and Collective Bargaining?

JEL classification: E24, J51, O33

Keywords: occupations, automation, collective bargaining, trade unions, wages

Authorised for publication by Stefano Scarpetta, Director, Directorate for Employment, Labour and Social Affairs

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JT03447561

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Acknowledgement

This paper was completed as part of the OECD Future of Work Fellowship Programme. For helpful comments and suggestions, I am grateful to Andrea Salvatori, Stijn Broecke, Diego Collado, Andrew Green, Dario Guarascio, Wim Van Lancker, Brian Nolan, and Linus Sioland. I also appreciate the feedback of participants at the 2018 ESPANet Conference in Vilnius, the "What drives inequality?" workshop in Luxembourg, the Herman Deleeck Centre for Social Policy Lunch Seminar series, and the "Labour Market Liberalization after the Lehman Crisis" workshop in Tokyo.

Abstract

Routine-biased technological change has emerged as a leading explanation for the differential wage growth of routine occupations, such as manufacturers or office clerks, relative to less routine occupations. Less clear, however, is how the effects of technological advancement on occupational wage trends vary across political-institutional context. This paper investigates the extent to which collective bargaining agreements and union coverage shape the relative wage growth of automatable occupations. Using data from the Luxembourg Income Study and the United States Current Population Survey, I measure the 'routine task intensity' of occupations across 15 OECD Member States and the 50 United States from the 1980s onward. Findings suggest that bargaining coverage is more consequential for the wage growth of high routine occupations relative to less routine occupations, and that high routine occupations lose coverage at a faster rate when bargaining coverage at the national level declines. As a result, declines in bargaining coverage within a country are associated with declining relative wage growth for automatable occupations. Estimates suggest that had union coverage in the United States not declined from 1984 levels, the earnings of high routine occupations might have grown at the same rate as low pay occupations between 1984 and 2015, rather than experiencing a relative wage decline. However, the findings also suggest that gains in the relative wage growth may increasingly come at the cost of reduced employment shares of automatable occupations.

Résumé

Les transformations technologiques visant à l'automatisation des tâches répétitives constituent désormais l'une des principales explications de la croissance différentielle des salaires des emplois routiniers, tels que ceux des ouvriers dans l'industrie ou des employés de bureau, par rapport aux emplois moins routiniers. Cependant, la manière dont les effets des avancées technologiques sur les tendances salariales professionnelles varient en fonction du contexte politique et institutionnel est moins claire. Ce document examine dans quelle mesure les conventions collectives et la couverture syndicale influent sur la croissance relative des salaires dans les professions automatisables. En utilisant les données de la Luxembourg Income Study et de la Current Population Survey des États-Unis, cette étude mesure « l'intensité des tâches routinières » de professions dans 15 États membres de l'OCDE et dans les 50 états américains depuis les années 1980. Les résultats suggèrent que la couverture conventionnelle est plus importante pour la croissance des salaires dans les professions hautement routinières que pour les professions moins routinières, et que les professions à caractère routinier perdent plus rapidement leur couverture lorsque la couverture conventionnelle au niveau national diminue. En conséquence, la baisse de la couverture conventionnelle dans un pays est associée à la baisse de la croissance relative des salaires pour les professions automatisables. Les estimations suggèrent que si la couverture syndicale aux États-Unis n'avait pas diminué par rapport aux niveaux de 1984, les revenus des professions hautement routinières auraient augmenté au même rythme que ceux des bas salaires entre 1984 et 2015, au lieu de connaître une baisse relative des salaires. Toutefois, les résultats suggèrent également que les gains de la croissance relative des salaires pourraient de plus en plus se faire au prix d'une réduction de la part de l'emploi dans les professions automatisables.

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1. Introduction

The effect of technological progress on the structure of employment and wages has emerged as a central concern of economics and social policy research. A dominant perspective in recent literature holds that advancements in technology contribute to differential wage and employment growth in routine occupations, such as manufacturers or office clerks, relative to less routine occupations, such as managers or service workers. Indeed, evidence suggests that declining demand for routine tasks has contributed to declining employment shares of automatable occupations across a broad range of advanced economies (Goos, Manning and Salomons 2014). With respect to wage growth, however the story is mixed. During the 1990s, the wages of automatable occupations in the United States grew at a slower rate than less routine occupations at the bottom and top of the wage distribution (Autor and Dorn 2013, Mishel, Schmitt and Shierholz 2013). Outside of the United States, however, this pattern of *occupational wage polarisation* has generally not been observed (Naticchioni, Ragusa and Massari 2014). In fact, wage growth of automatable occupations continues to outpace that of low-routine, low-pay occupations in many advanced economies (Naticchioni, Ragusa and Massari 2014).

This paper investigates how the strength of labour market institutions affects variance in occupational wage trends. Specifically, I analyze how unions and collective bargaining coverage moderate the effect of routine-biased technological change on the relative wage growth of high routine occupations. Using data from LIS, the Cross-National Data Center in Luxembourg, I measure the task composition of occupations across 15 OECD Member States from the 1980s onward. Using the task composition data, I separate the sample of 1.4 million employed adults into three occupation categories: (1) high routine task intensive (RTI) occupations, (2) low RTI and low pay occupations, and (3) low RTI and high pay occupations. High RTI occupations are those that are most susceptible to automation. I then measure the effect of within-country changes in levels of collective bargaining coverage on wage trends of high RTI occupations relative to the two sets of lower RTI occupations.

I posit that declining levels of collective bargaining coverage within a country are associated with declining wage growth for high RTI occupations relative to low RTI occupations, and the low-pay variant in particular. Underlying this hypothesis are four mechanisms through which changes in bargaining coverage might affect the relative wage growth of automatable jobs. First, bargaining coverage might be *more consequential* for the earnings of high RTI occupations relative to low RTI occupations. Second, bargaining coverage might *decline at a faster rate* among high RTI jobs relative to other occupation types when coverage at the national level declines. Third, an *employment effect* might exist, in which workers in high RTI occupations maintain higher earnings over time, but at the cost of accelerated employment reduction. Fourth, an *investment effect* might exist, in which rising levels of bargaining coverage within an industry affect the rate at which employers invest in new technologies.

Though my primary estimation strategy investigates how changes in bargaining coverage at the national level shape relative wage trends of automatable occupations, it may in some countries be the case that technological change is directly associated with declines in bargaining coverage. For example, if bargaining coverage is concentrated in manufacturing, the decline of manufacturing jobs may directly lead to a decline in national

rates of bargaining coverage. To account for this potential mechanical relationship, I re-estimate my analyses on a second sample – the 50 United States – while measuring bargaining coverage *among high routine occupations* at the state and industry level.[1] Thus, even as employment shares of high routine jobs decline, the bargaining coverage of employees within these occupations need not mechanically decline. This sensitivity check has the benefit of testing the study's hypotheses on a second sample while leveraging within-industry differences in bargaining coverage to explain occupational wage trends.

The findings from the analyses suggest that bargaining institutions play a role in shaping the wage growth of automatable occupations relative to low pay, low routine occupations. When bargaining coverage within a country declines, automatable occupations experience less favourable wage growth relative to service-sector occupations. This association appears to be in part due to the higher relative wage premium that automatable occupations receive when working in a state and industry with higher levels of unionisation. In other words, declining unionisation tends to be more consequential for the relative wage progression of automatable jobs. In a counterfactual analysis across the 50 United States, for example, I estimate that if levels of bargaining coverage among high routine occupations had not declined from their 1984 levels, earnings of high routine jobs might have grown at the same rate as low pay occupations between 1984 and 2015, rather than low pay jobs outpacing the former. Moreover, the observed pattern of occupational wage polarisation in the United States during the 1990s might have been less severe. However, the findings also suggest that the gains in the relative wage growth of automatable jobs may increasingly come at a cost. As demand for routine tasks continues to decline, the effect of rising bargaining coverage among automatable occupations appears to have an increasingly negative effect on employment shares of automatable jobs within a given state and industry.

[1] Data on individual - industry-level bargaining coverage are not available for most of the countries and years examined in the cross-national analysis.

2. Background & Theory

2.1. Automation & Occupational Wages

Economic models of routine-biased technological change (RBTC) suggest that technological progress generates two primary consequences with respect to employment and wage patterns (Acemoglu and Autor 2011, Autor, Levy and Murnane 2003, Goos, Manning and Salomons 2014). One is the polarisation of employment structures: high routine task intensive (RTI) occupations, the most susceptible to automation, tend to be in the middle of the wage and skill distributions (Acemoglu and Autor 2011). Their decline thus leads to a dip in employment shares near the median of the wage distribution. Meanwhile, technological advancements are theorised to take a factor-augmenting form for higher-skill occupations, contributing to rising employment shares at the top the wage and skills distributions (Autor, Levy and Murnane 2003, Autor and Dorn 2013).[2] Though the decline in employment shares of high RTI occupations has been written about extensively in the context of the United States, evidence suggests that the trend is also pervasive throughout advanced economies in Europe (Goos, Manning and Salomons 2009, OECD 2017).

A second potential consequence of RBTC is that wages of high RTI occupations may experience less favorable wage growth relative to low RTI occupations (Acemoglu and Autor 2011, Goos, Manning and Salomons 2009). If declining demand for routine tasks translates into declining relative wages among high RTI occupations, then *wage* polarisation, in addition to employment polarisation, might occur (Böhm 2017, Firpo, Fortin and Lemieux 2011). In the United States during the 1990s, for example, the wages of occupations at the bottom and top of the wage distribution increased at a greater rate than wages of occupations in the middle of the distribution (Acemoglu and Autor 2011). However, evidence from other advanced economies (and other decades within the United States) suggests that wage polarisation is far from the norm. In Germany, for example, occupational polarisation has occurred *without* wage polarisation (Antonczyk, DeLeire and Fitzenberger 2010). Looking more broadly at a number of EU Member States, Naticchioni, Ragusa and Massari (2014) also find that technological change has not led to the polarisation of wages. In other words, job polarisation appears to be pervasive across advanced economies, but *wage* polarisation has often not followed. Instead, middle-pay occupations have generally experienced wage growth at least on par with low-pay occupations (Naticchioni, Ragusa and Massari 2014).

Several factors might help to explain the disconnect the between employment polarisation and wage polarisation. First, at the bottom of the earnings distribution, elastic labour supply among service-sector jobs is likely to be a depressant on their real wage growth (Autor 2015). This is particularly true if workers displaced from high RTI occupations are also left

[2] Advanced technologies tend to benefit owners of capital and high-skill workers which, combined with increased consumption of goods and services among higher-paid workers, is theorised to contribute to a rise of employment shares among low-skill occupations, typically in the services sector (Autor, 2015). Some scholars, however, disagree on the extent to which advancements in technology deserve credit for employment polarisation (Salvatori, 2015).

to compete for low pay jobs. Without a rise in wages of low pay occupations, then wage polarisation is less likely to occur, even if wage growth of high RTI occupations is stagnant.

Second, the wages of high RTI occupations will not necessarily change in accordance with declining task prices. Despite a decrease in demand, high RTI occupations could maintain stable wage growth if, as one example, the workers who remain in the occupations have adequate bargaining power to negotiate against real wage declines. If high RTI occupations do experience real wage growth, then they are, of course, less likely to experience a *relative* wage decline, even if low pay and high pay occupations were to experience wage growth, as well.

The observed lack of relative wage declines for automatable occupations is worthy of investigation for several reasons. First, it poses *prima facie* evidence against an important feature of the RBTC hypothesis. As Acemoglu and Autor (2011) describe, a central innovation of their "tasks framework" is its ability to simultaneously explain the decline of wages in high RTI occupations and the rise of wages in low-pay and high-pay occupations (wage polarisation) (Mishel, Schmitt and Shierholz 2013). That wage trends across many advanced economies do not align with this pattern raises an important question: under which conditions do the wages of high RTI occupations continue to grow at a faster rate than low-RTI, low-pay occupations? Before, I outlined two mechanisms that could contribute to the observed lack of wage polarisation: increased labour supply placing downward pressure on wages of low pay occupations, and workers in high RTI occupations maintaining their wage growth despite declining demand for routine tasks. One factor that might affect both of these patterns, and a central focus of this paper, is the bargaining power of organised labour.

Comparatively strong trade unions and widespread collective bargaining agreements are generally credited for producing more rigid and egalitarian wage structures in Western and Northern Europe, as well as generating higher relative wage premiums for automatable jobs (Denice and Rosenfeld 2018, OECD 2011). It is plausible, then, that these same labour market institutions affect the relative wage growth of high RTI occupations.

2.2. Labour Market Institutions & Inequality

Labour market institutions have largely been absent in empirical analyses of the effect of automation on occupational wage trends. This is perhaps due to an extensive focus on a single country (the United StatesU), or perhaps due to a greater focus on the employment effects of technological change. Regardless of cause, the relegation of institutions is surprising given the rich history of literature on their role in shaping the wage distribution within and between occupations (Biegert 2017, Brady 2009, Katz and Autor 1999, OECD 2011, Western and Rosenfeld 2011). We might plausibly expect that countries and industries with higher levels of unionisation, or those with standards on wage structures built into collective bargaining agreements, will experience different trends in occupational wage growth despite declining demand for routine tasks. Similarly, variance in levels of collective bargaining coverage *within* a country over time may affect the relative wage trends of automatable occupations.

A large body of research has established a relationship between comparatively high levels of union membership and low levels of wage inequality (OECD 2018, Visser and Checchi 2011, Western and Rosenfeld 2011), in-work poverty (Brady et al., 2013), and wage premiums for automatable occupations (Denice and Rosenfeld 2018). Unions are often involved in negotiating *collective bargaining agreements* for their members, or for

employed individuals across entire sectors. Collective bargaining refers to agreements between employers and workers' organisations on conditions relating to terms of employment, standards on working conditions, wage structures, dismissal guidelines, and more (OECD and ILO 2018). Bargaining *coverage* is operationalised as the share of workers who are protected under the bargaining agreement. In countries like the United States, where bargaining agreements are most often negotiated at the firm level, little difference exists between levels of union coverage and bargaining coverage: those in unions tend to be the workers covered. In most OECD Member States, however, trade union agreements extend beyond non-union members. This is in large part due to administrative extension rules, which extend the terms of collective agreements at the sectoral level to firms that have not signed the agreement (OECD 2017). The extent to which extension rules apply varies by country: in Southern Europe, for example, there tends to be greater discrepancy between union membership (relatively low) and collective bargaining coverage (relatively high). As such, bargaining coverage is often recognised as a more useful indicator than trade union coverage in estimating influence of organised labour on wage structures (OECD and ILO 2018).

Changes in levels of bargaining coverage within countries are, in some cases, likely to be channeled through the decentralisation of wage bargaining (from, say, sectoral to firm levels) or declining levels of bargaining coordination. Nonetheless, this paper gives analytical focus to bargaining coverage rather than indicators of (de)centralisation or coordination for several reasons. First, within-country variation in bargaining coverage is much greater than variation in centralisation or coordination. This is particularly true for countries, such as Canada and the United States, which have featured uncoordinated, firm-level bargaining throughout recent history (no variation over time), yet have experienced large variation in levels of bargaining coverage. Operationalising the centralisation of wage bargaining would fail to pick up the large declines in coverage within these countries. Second, even in countries which have historically featured more centralised and/or coordinated bargaining processes, the decentralisation or decline of coordination has not always translated to declines in bargaining coverage. Denmark, for example, underwent decentralisation of bargaining in the late 1980s, yet coverage in 2013 (84%) was as broad as in 1980 (82%). Austria, the Netherlands, and other countries experiencing an "organised decentralisation" share similar experiences (OECD 2018, Traxler 1995).

According to OECD (2017), around 17% of employees were members of trade unions in 2015, compared to more than 30% in 1985. In 1985, about 45% of workers in OECD Member States were covered by collective bargaining agreements, but only 33% in 2015. In Annex A, I provide details on trends in levels of bargaining coverage and unionisation among countries included within this analysis. As can be observed, bargaining coverage and unionisation have declined in recent decades across many, but not all, of the 15 OECD Member States included in this study.

2.3. Hypotheses & Mechanisms

My primary hypothesis states that declining levels of collective bargaining coverage within a country will be associated with less favorable wage growth for high RTI occupations relative to lower RTI occupations. An underlying premise to this hypothesis is that unions and/or bargaining coverage provide covered workers with a wage premium relative to non-covered workers (assuming all other characteristics of the worker are identical). The presence of a union premium or collective bargaining premium is supported by a large body of research (Denice and Rosenfeld 2018, Hirsch 2004, Nickell and Andrews 1983,

Western and Rosenfeld 2011). For the purpose of the paper, we can define the bargaining premium for a high RTI occupation (B_h, the subscript *h* denoting a high RTI occupation) as the wage difference between a covered worker ($W_{h,\ u=1}$) and an identical worker not covered by a union or bargaining agreement ($W_{h,\ u=0}$). This leads to the following:

$$B_h = W_{h,u=1} - W_{h,u=0} \qquad \textbf{(1)}$$

For simplicity, let's assume that the wage of a high RTI occupation (W_h) can thus be separated into two parts: a competitive wage ($W_{h,u=0}$) and a potential bargaining premium (B_h) when the worker is covered by a union or bargaining agreement (U_h=1) (Hirsch and Schumacher 2001). We can write this formally as:

$$W_h = W_{h,u=0} + (B_h * U_h) \qquad \textbf{(2)}$$

The mean wages for a high RTI occupation ($\overline{W_h}$) and low RTI ($\overline{W_l}$) occupation for an otherwise identical set of workers can thus be simplified as:

$$\overline{W_h} = \overline{W_{h,u=0}} + \overline{(B_h\ *\ U_h)}$$

$$\overline{W_l} = \overline{W_{l,u=0}} + \overline{(B_l\ *\ U_l)} \qquad \textbf{(3)}$$

Given this, we can set forth at least two scenarios in which a decline in bargaining coverage (*U)* within a country would lead to less favorable wage growth for high RTI occupations relative to low RTI occupations. The first scenario implies that bargaining coverage is *more consequential* to the wages of high RTI occupations relative to other occupations. The second scenario implies bargaining coverage is *declining faster* for high RTI occupations relative to low RTI occupations. I describe these in turn.

In the first scenario, let's assume that the relative bargaining premium for high RTI occupations is higher in time *t* than for low pay occupations $\left(\frac{\overline{B_h}}{W_{h,u=0}} > \frac{\overline{B_l}}{W_{l,u=0}}\right)$.

To find this pattern would be consistent with evidence from Denice and Rosenfeld (2018), who observe that the union premium in the United States is higher for automatable jobs relative to service-sector occupations. Given this, then the following is true: an even decline in bargaining coverage (*U)* across occupation types from *t* to *t+1* will lead to declining wage growth for the average high RTI worker relative to the average low RTI worker (holding $\overline{W_{h,u=0}}$ and $\bar{B}$ constant).[3] In other words, if the relative bargaining premium is higher for high RTI jobs, then losing the premium will contribute to less favorable wage growth. I return to the effects of bargaining coverage on competitive wages ($W_{h,u=0}$) in a moment.

The second scenario, in which bargaining coverage declines faster for high RTI occupations relative to other occupations, is not conditional on $\frac{\overline{B_h}}{W_{h,u=0}} > \frac{\overline{B_l}}{W_{l,u=0}}$.

[3] If the bargaining premium for high RTI occupations ($\overline{B_h}$) were to rise despite declining levels of unionisation, then the net change in mean wages need not be negative; however, economic theory and empirical evidence suggest, instead, that declining union membership should be associated with a flat or declining premium for occupations experiencing declining demand (Hirsch and Schumacher, 2001).

The claim is as follows: even if the relative collective bargaining premiums were to be equal across occupation types, high RTI occupations will experience declining relative wage growth if bargaining coverage declines at a faster rate for high RTI workers ($\overline{U_h}$) relative to other occupation types ($\overline{U_l}$), all else constant.

In Annex B, I provide empirical evidence that offers initial, but incomplete support for both of these premises. Consistent with prior evidence, I find that within the United States, the relative union premium for high RTI occupations is consistently higher than that of low RTI occupations. Within the EU and United States, union membership among high RTI occupations does, indeed, decline more rapidly than low pay occupations when unionisation at the national level declines.[4] If this is also the case for trends in bargaining coverage, then there would be initial reason to believe, as this paper's primary hypothesis states, that declines in bargaining coverage at the national level promote declining relative wage growth of high RTI occupations.

Changes in bargaining coverage within a country can also affect rates of wage growth across occupation types in other ways that reinforce this study's hypothesis. I highlight and investigate two of these potential mechanisms: an *employment* effect or an *investment* effect. The employment effect hypothesis suggests that high RTI occupations can achieve higher relative wage growth, but at the cost of accelerated reductions in employment shares. In other words, employers might compensate for paying routine occupations above-market value through the dismissal of employees or through declines in hiring. Rather than seeing bargaining coverage decline faster among high RTI occupations, as proposed in the prior mechanism, an employment effect might lead to workers covered under a bargaining agreement maintaining their jobs and relative wage growth, but at the expense of employment shares among non-covered workers**.** This hypothesis has its roots in the insider/outsider literature in economics and the dualisation literature in social policy (Emmenegger 2012, Lindbeck and Snower 2001, Rueda 2014). Both strands of literature demonstrate how *labour market insiders* – those covered by unions or collective bargaining agreements – can achieve higher rents, but at the expense of the *labour market outsiders*, such as new labour market entrants, jobseekers, and workers in precarious or low-paid employment. This insider/outsider divide may contribute to the observed lack of occupational wage polarisation in countries with stronger bargaining institutions. As Autor and Dorn (2013) point out, the decline of wages in low-pay, low-RTI occupations in the United States in recent years is partly due to more middle-skill workers and new labour market entrants competing for the low pay occupations. If unions and bargaining coverage protect the relative wages of a declining share of 'insiders' (lifting up $\overline{W_h}$), then it is perhaps the case that competition among a larger share of 'outsiders' places downward pressure on wages of low pay, low routine occupations (constraints on $\overline{W_l}$).

The investment effect hypothesis, on the other hand, suggests that rising collective bargaining coverage discourages employers from investing in productivity-enhancing technologies. This would have the effect of slowing the shift in demand away from routine tasks and thus inhibiting downward pressure on the wages of high RTI occupations ($\overline{W_h}$) (and would perhaps even inhibit *employment* polarisation). This hypothesis has its roots in

[4] As I detail in Annex B, I use data from the European Social Survey States to estimate union membership among occupation types from 2002 onward within 22 EU Member States. For the United States, I use data from the CPS Merged Outgoing Rotation Groups (see also Annex D). As described before, union membership is an appropriate proxy for bargaining coverage in the United States, but is a less appropriate proxy among many EU Member States. However, individual-level data on bargaining coverage within EU Member States is unavailable.

the literature around capital holdup (Card, Devicienti and Maida 2014, Denny and Nickell 1991, Green and Sand 2015). A holdup problem exists when bargaining diverts returns from capital investments to workers, encouraging firms to under-invest (Cardullo, Conti and Sulis 2015). Indeed, prior studies have found that firms with higher collective bargaining coverage (or union coverage) are less likely to invest in capital relative to firms with fewer covered employees (Cardullo, Conti and Sulis 2015, Connolly, Hirsch and Hirschey 1986, Denny and Nickell 1991, Hirsch 2004). This appears to be the case for non-ICT capital, such as machinery, as well as investment into information and communication technologies (ICT) (Hirsch 2004). The latter – ICT investment – is of particular interest in this analysis, as increases in ICT investment are generally associated with the technological replacement of routine occupations (Autor, Levy and Murnane 2003). If capital holdup contributes to the higher relative wage growth of high RTI workers, we might expect to find evidence that rising levels of bargaining coverage within a country depress new investment into ICT, particularly in industries with higher shares of high RTI occupations. More specifically, we might expect to find that increasing bargaining coverage contributes to greater wage growth, with greater wage growth providing firms a disincentive to invest in ICT capital. Reduced investment would then slow declines in demand for routine tasks, contributing to more favourable wage growth for high RTI occupations.[5]

In contrast, there are at least two plausible arguments to suggest that sectors with higher shares of high RTI workers will invest *more* in ICT capital when bargaining coverage is higher. First, the higher wages achieved by stronger bargaining coverage may prompt firms to enhance productivity in order to compensate for the higher wages. As such, firms may invest more into ICT capital, or use the same level of investment for different purposes, as a strategy to enhance the output of their workers (Metcalf 2002). A second possible outcome, and related to the potential employment effect, is that firms will increase investment into ICT for the purpose of replacing high-cost labour (Hirsch 2004). In either of these scenarios, we might find that higher bargaining coverage within a country and higher shares of automatable workers contribute to increased investment into new technologies.

To summarise, declining bargaining coverage at the national level might lead to declining relative wage growth for high RTI occupations through a combination of the following mechanisms: (1) bargaining coverage might be *more consequential* for the earnings of high RTI occupations, (2) bargaining coverage might *decline a faster rate* among high RTI jobs relative to other occupation types when coverage at the national level declines, or there may exist an (3) employment effect or (4) investment effect.

[5] This relationship simultaneous implies that capital holdup contributes to higher wages, while higher wages (through bargaining coverage) contribute to capital holdup. This endogenous relationship presents challenges in the estimation strategy, which I return to in the next section.

3. Data & Methods

3.1. Data Sources

My primary analysis uses micro-data from LIS, the Cross-National Data Center in Luxembourg, to assess the relationship between bargaining coverage and occupational wage trends. LIS provides harmonised demographic, employment, and income data across more than 40 countries spanning more than 40 years. This study focuses primarily on earnings of workers in high-routine occupations. As such, case selection was limited to all advanced economies within LIS for which data on four necessary variables were available: employment status, earnings from formal employment, occupation of employment, and the routine task intensity of the occupation. In practice, availability of the latter two variables were the excluding criteria for many countries (discussed more below). A total of 1.4 million individuals across 15 countries and time-points spanning 34 years (1979 to 2013) were included in this analysis. LIS provides data in 'waves' (generally three to four years apart) rather than annual surveys. For the United States, for example, the three most recent years of data included in this study are 2007, 2010, and 2013. I apply the LIS 'normalised' weights so that each country-year, regardless of population size, carries the same aggregate weight. A complete list of countries included, as well as sample sizes, is presented in Annex A.

My estimation strategy measures how variation in levels of collective bargaining coverage within a country affect the relative wage growth of high RTI occupations. It may be the case, however, that technological change simultaneously drives down earnings of high RTI occupations *and* levels of collective bargaining coverage. One step toward sidestepping this mechanical relationship would be to operationalise collective bargaining levels not as the share of covered employees within a *country*, but as the bargaining coverage of high routine occupations within each industry in each country. In the first approach, levels of bargaining coverage within a country may decline as employment shares of manufacturers decline if bargaining coverage is particularly concentrated in manufacturing (as one example). In the second approach, I measure the coverage *among* manufacturers; thus, even as employment shares of manufacturers decline, the share of the remaining workers who are covered need not experience a mechanical decline. If the hypotheses advanced in this paper hold, then declining shares of bargaining coverage among high RTI occupations should be associated with declining relative wage gains for high RTI occupations.

Measuring bargaining coverage at the occupational level is not possible through LIS or most countries' respective datasets; it is possible, however, across the 50 United States.[6] State-level variation of rates of union coverage in the United States have been linked in prior work to cross-state differences in wage patterns (Brady, Baker and Finnigan 2013, Western and Rosenfeld 2011). Here, I use the Current Population Survey Merged Outgoing Rotation Group (CPS MORG) to produce three-year rolling averages of union coverage (akin to collective bargaining coverage in the United States) among high RTI occupations within each industry in each state from 1984 to 2015. Merging the state-industry union data

[6] The European Social Survey does allow for estimation of occupation- and industry-level union membership, but only for every other year from 2002 onward, and only for EU Member States.

back into the Current Population Survey (CPS ASEC) provides a sample of nearly 2 million employed adults across the United States Annex C provides more information on the data source and construction of the industry-level union variables. I conduct my empirical analyses on both datasets: the cross-national analysis in LIS and the cross-state analysis in the CPS ASEC. In addition to addressing concerns of endogeneity, this cross-state analysis has the benefit of testing the study's hypotheses on a second sample.

In both samples, I measure occupational earnings as the log gross earnings of employed workers on an annual basis (labour income in the prior year), as data on hourly wages are unavailable or widely missing in LIS for many countries in this study.[7] Hourly wage data are available in the cross-state United States sample; however, I utilise annual earnings in the primary analyses to remain consistent with the cross-national analysis. As a sensitivity check, however, I re-estimate the results in the cross-state sample using hourly wages and present these in Annex F (Table A F.1.); the findings are consistent with the primary analysis. I use the LIS PPPs to deflate national currency values to 2011 USD for each country. Self-employed individuals are excluded. I top- and bottom-code annual earnings at the 1st and 99th percentiles in each respective country-year.

Data on bargaining coverage are pulled from the ICTWSS Database (Visser 2015). In testing the investment effect hypothesis, I use two industry-level measures of investment from the EU-KLEMS database (O'Mahony and Timmer 2009). The first is a proxy for ICT capital investment: the contribution of ICT capital services (such as computers, software, and communication technologies) to value added growth at the country and industry level. The second is a proxy for non-ICT capital investment: the contribution of non-ICT capital services to value-added growth. This follows similar analyses using the EU KLEMS data (Naticchioni, Ragusa and Massari 2014, Spiezia 2012). As the data are not disaggregated by state within the United States, I only test for an investment effect using the cross-national sample.

3.2. Calculating Routine Task Intensity

I follow Autor and Dorn (2013) in measuring the routine task intensity (RTI) of all occupations within the dataset. The RTI index has become the standard practice for measuring the task content of occupations (Goos, Manning and Salomons 2014:2511). Routine tasks consist of repeated sequence of actions and are more easily replaceable through technological innovations. A higher RTI score thus indicates that an occupation is more 'routine-task intensive' and, thus, can more readily be automated. In Annex D, I provide more information on the construction of the RTI index.

Recent work has extended the reach of the RTI index to measure the task content of occupations in the European Union (Goos, Manning and Salomons 2014). Specifically, these authors have harmonised the occupational codes (ISCO) of the United States data to those within the EU Labour Force Survey in order to utilise RTI indicators for European occupations. Taking this practice a step further, Mahutga, Curran and Roberts (2018) have harmonised consistent occupation codes across a large set of countries within LIS to allow the integration of RTI indicators across continents (and beyond the United States and Western Europe). I utilise the harmonised occupation codes from Mahutga, Curran and

[7] Hourly wages are unavailable in Australia and Denmark. The data were missing for more than half of cases in Finland, France, Greece, and Spain.

Roberts (2018) to create the RTI indicators for each occupation in the 15 countries included in this analysis. In the cross-national analysis with LIS, the task data is merged with occupations using the two-digit ISCO occupation classification. In the cross-state sample with the CPS ASEC, task data is merged in at the more precise three-digit ISCO categorisation.[8] To ensure that differences in the two- and three-digit occupation codes do not drive my results, I also re-estimate the cross-state sample using the same two-digit ISCO codes as in the cross-national sample. The sensitivity check is presented in Annex F (Table A F.1.); the findings are consistent with the primary analyses.

Table 3.1. Description of High Routine-Task Intensive Occupations (2013)

			United States		Non-United States Countries	
ISCO-88 Code	Job Title	RTI Score	Wage / Median	Share of Employed	Wage / Median	Share of Employed
41	Office clerks	2.40	0.94	4.61	0.98	7.40
42	Customer services clerks	1.55	0.62	4.76	0.96	2.38
52	Sales workers	0.17	0.87	2.93	0.94	5.25
72	Metal, machinery and related trades workers	0.58	1.29	4.65	0.99	4.69
73	Precision, handicraft, printing and related trades workers	1.72	1.03	0.17	0.99	0.47
74	Other craft and related trade workers	1.36	0.77	0.75	0.97	1.55
81	Stationary plant and machine operators	0.45	1.46	0.47	0.99	0.37
82	Machine operators and assemblers	0.62	0.96	3.52	0.99	1.95
93	Labourers in mining, construction, manufacturing and transport	0.57	0.78	3.61	0.95	2.47
	Mean:	**1.05**	**0.97**	**2.83**	**0.98**	**2.95**

Note: Table depicts occupations that are in top one-third of RTI distribution in each country within analysis. The non-United States countries for which data were available in 2013 include AT, DK, FI, DE, EL, IL, NL, ES, and CH. Wage / Median indicates the mean wage of the occupation relative to the median wage across all occupations.

Following Lordan and Neumark (2017), I identify "high RTI occupations" as those above the 66th percentile of the RTI distribution of all occupations. Thus, any occupation in any country with a RTI score above 0.15 (the 66th percentile) is considered to be high RTI.[9] This distinction of "high" RTI is, of course, purely relative: these are the occupations that are estimated to be *more* at risk than other occupations, but further advancements in technology could certainly place many "less RTI" occupations at risk of automation, as well.

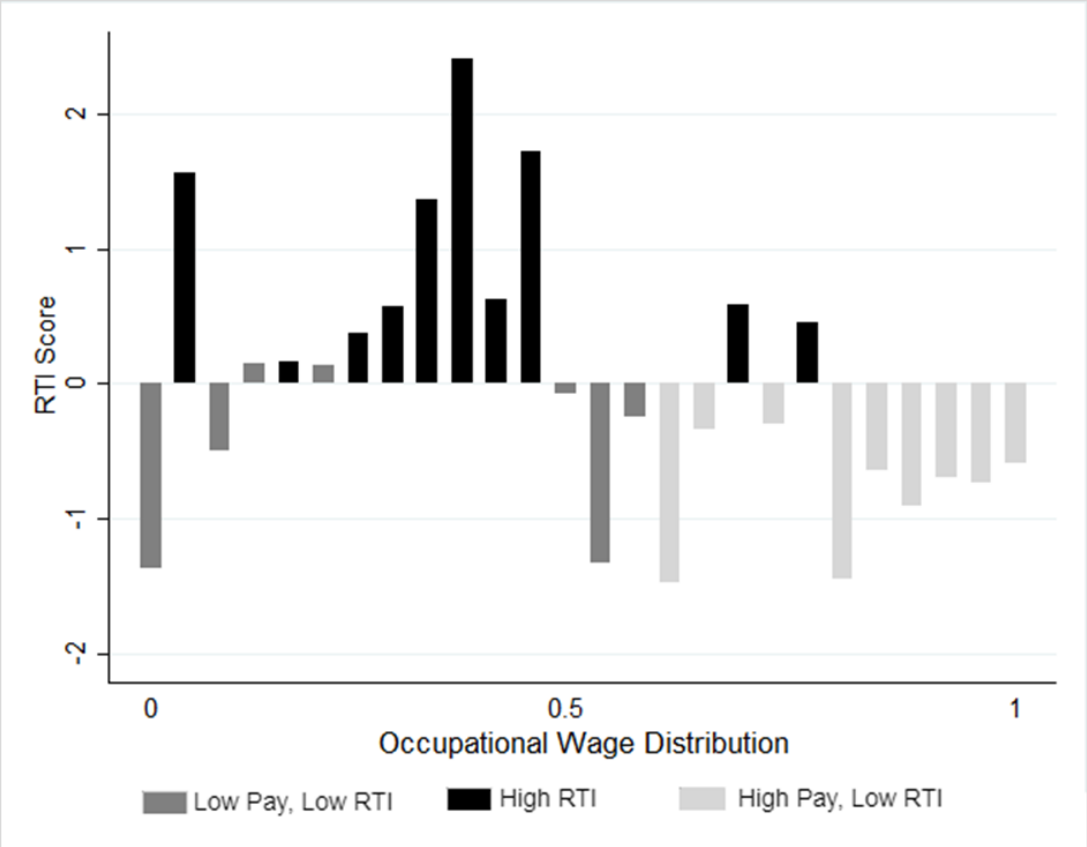
Table 3.1 identifies the high RTI occupations applied in this paper. An important feature of these occupations is their place in the overall wage distribution: near the median. This is true not only in the United States, but also in the non-United States countries in this

[8] In total, there are 27 separate occupation groups using the two-digit classification, and 114 occupation groups using the three-digit classification. In the cross-state sample, I apply the 'consistent' occupation coding scheme, as described in Acemoglu and Autor (2011), which largely accounts for occupational coding changes in 2003.

[9] I also re-run the analyses using two alternative conceptualisations of 'highly automatable' occupations: 1) utilising an employment-weighted RTI distribution in each country's respective data to mark high RTI occupations, and 2) matching the Goos, Manning, and Salomons (2009) definition of "middling occupations", in which occupations are ranked according to wages rather than RTI score. Neither approach substantially alters the primary findings.

analysis, as shown in the right half of Table 3.1. High RTI occupations in the non-United States countries feature an unweighted mean annual wage of 98% of the median in 2013, while those in the United States fall in at 97% of the American median. As discussed previously, the decline in employment shares and wages of these high RTI occupations is the central analytical focus of theories of routine-biased technological change.

Figure 3.1. Wage Distribution of High RTI and Low RTI Occupations



Note: Data via 2013 wave of LIS with routine task indicators imported from Mahutga et al. (2013). RTI score represents the standardised level of routine task intensity for the occupation.

I then split the low RTI occupations (those in the bottom two-third of the skill distribution) into two categories: low pay and high pay occupations. I use the first two years of each country's data to calculate whether the low RTI occupations are low or high pay. Low RTI occupations with median earnings below the overall median are placed into the low-pay categories, while those with median earnings above the overall median are labeled as high pay. For brevity, I hereafter refer to the two groups as "low pay" and "high pay". Categorising occupations by mean (rather than median) earnings produces similar results. A country's occupation categories are kept consistent across all years of its respective data. Figure 3.1. provides a depiction of the relative earnings and RTI scores of the three occupation categories for the average country in the LIS sample in 2013. On the X-axis, occupations are sorted from lowest mean value of annual earnings to highest mean value of annual earnings. On the Y-axis, each occupation's level of routine task intensity is depicted. As can be seen, four of the six lowest paid occupations are low RTI, while the six

highest paid occupations are also low RTI. The high RTI occupations are clustered toward the middle.

3.3. Estimation Strategy

I will first estimate wage trends in high pay and low pay occupations relative to high RTI occupations, while controlling for individual characteristics that likely affect labour supply. This estimation is modeled as follows:

$$\log(Wage)_{jnst} = \beta_1 HighPay_j + \beta_2 LowPay_j + \beta_3\left(HighPay_j \cdot Year_t\right) + \beta_4\left(LowPay_j \cdot Year_t\right) + \beta_5 X_j + [\alpha_s \cdot \alpha_n \cdot \alpha_t] + \varepsilon_{jnst} \quad \textbf{(4)}$$

in which the outcome variable is the log wage of an individual (j) working in industry (n) in country (s) and year (t). *HighPay* and *LowPay* represent dummy variables to indicate the occupation's category, while high RTI occupations are set as the reference group. The $Year_t$ variables included in the interaction terms represent linear time trends, following similar specifications from and Goos, Manning and Salomons (2014) and Mahutga, Curran and Roberts (2018). Thus, if β_3 is positive and significant, this would imply that the earnings of high pay (low RTI) occupations are experiencing more favourable wage growth than high RTI occupations, independent of composition effects, such as a rise in educational attainment. If β_4 were to also be positive and significant, this would signal the presence of occupational wage polarisation: low pay and high pay occupations would both be growing faster than high RTI occupations. Vector X controls for demographic features (age, education level, and sex). Note that I also include country-industry-year ($\alpha_s \cdot \alpha_n \cdot \alpha_t$) fixed effects. In practice, this takes into account that wage trends are likely to vary by country and industry. As a result of the country-industry-year interactions, the main effect of any country-level variables (such as bargaining coverage) drops out, and the interaction terms become the coefficients of interest. I apply robust standard errors clustered at the country level.

I then extend Equation (4) to measure the moderating role of collective bargaining coverage on the relative wage trends. Adding in bargaining coverage (CBC) creates a three-way interaction between the high pay / low pay dummies, the linear year trend, and collective bargaining coverage (at the country level in the cross-national sample, and among high RTI occupations within each industry and state in the cross-state analysis):

$$\log(Wage)_{jnst} = \beta_1 HighPay_j + \beta_2 LowPay_j + \ldots + \beta_3\left(HighPay_j \cdot Year_t\right) + \beta_4\left(LowPay_j \cdot Year_t\right) + \beta_5\left(LowPay_j \cdot Year_t \cdot CBC_{st}\right) + \beta_6\left(HighPay_j \cdot Year_t \cdot CBC_{st}\right) + \beta_7 X_j + [\alpha_s \cdot \alpha_n \cdot \alpha_t] + \varepsilon_{ist} \quad \textbf{(5)}$$

Note that the three-way interaction also creates interactions between CBC and year, as well as the high pay / low pay dummies and CBC; I conceal these from the formal estimation above solely for brevity. The primary coefficients of interest become β_5 and β_6. A negative and significant slope would suggest that rising levels of collective bargaining coverage within a country are associated with more favorable wage growth for high RTI occupations (the reference group) relative to the low RTI occupation group. This finding would

corroborate the study's primary hypothesis that declining collective bargaining contributes to declining relative wage growth for automatable occupations.[10]

I then turn toward understanding the mechanisms by which higher bargaining coverage within a country can achieve greater wage growth for high RTI occupations despite declining demand for routine tasks. To test the *employment effect* hypothesis, I measure whether rising levels of collective bargaining coverage increasingly lead to reductions in the likelihood that an employed adult works in a high RTI occupation. Specifically, I estimate the following:

$$HighRTI_{jnst} = \beta_1(CBC_{st} \cdot Year_t) + \beta_2 \mathrm{X}_j + [\alpha_s \cdot \alpha_n \cdot \alpha_t] + \varepsilon_{jnst} \quad \textbf{(6)}$$

$HighRTI_{jnst}$ is a binary indicator of whether an individual (*j*) working in industry (*n*) in country (*s*) and year (*t*) is in a high RTI occupation, as opposed to a low RTI (low pay or high pay) occupation. If β_1 is negative and significant, this would suggest that rising bargaining coverage within a country increasingly contributes to the decline of high RTI occupations relative to employment shares of other occupations, independent of compositional changes in education, age, or sex. This would be in line with the employment effect hypothesis. Notably, this estimation does not include unemployed individuals, as LIS does not provide information on occupation history for jobless adults. This is a limitation I return to later.

Finally, I test the *investment effect* hypothesis. Here, I convert the data to country-industry and year panel data, as the outcome variable – industry-level investment – does not vary by individuals/occupations within country-industries. I estimate whether industries with higher shares of high RTI occupations are more likely to increase investments into ICT technologies when collective bargaining coverage in the country declines. As a reminder, the proxy for (non-)ICT investment applied here is the contribution of (non-)ICT capital services to value added growth The equation is estimated as:

$$\mathrm{ICT}_{nst} = \beta_1(CBC_{st} \cdot Year_t) + \beta_2(RTI_{nst} \cdot Year_t) + \beta_3(RTI_{nst} \cdot CBC_{st}) + \beta_4(RTI_{nst} \cdot CBC_{st} \cdot Year_t) + [\alpha_s \cdot \alpha_n] + \alpha_t + \varepsilon_{nst} \quad \textbf{(7)}$$

in which *RTI* represents the share of high RTI occupations within the given industry, country, and year. I present the estimates for both of the investment measures (ICT and non-ICT). In sensitivity checks, I test a one-year lag for the RTI and bargaining coverage variables, as well as weights for country-industry employment levels. The results are substantively similar across each specification.

[10] Of course, the linear time-trend interactions estimated in these equations measure any time-variant factors that may affect wage growth – not only advancements in technology. Nonetheless, I follow prior literature in operationalising the linear time-trends with an expectation that they appropriately reflect declining demand for routine tasks. Given that new technologies increasingly affect even non-routine jobs, such as automobile drivers, the assumptions that the time-trend approximates 'routine-biased' technological change may be a limitation of this study.

4. Findings

I first present descriptive findings on trends in relative wage growth of high RTI occupations across country. My hypotheses and estimation strategy focus on the effect of within-country variation in levels of collective bargaining coverage on the relative wage growth of automation occupations. Given this, I will focus mostly on the within-country relationships of bargaining coverage and relative wage growth. Nonetheless, it is perhaps instructive to first examine this relationship *across* countries to see if the anticipated relationships exist.

Figure 4.1. Wage growth of high RTI occupations relative to low pay (left) and high pay (right) occupations by country's mean level of bargaining coverage

Note: R=0.35 (low pay, left panel) and R=0.55 (high pay, right panel). Mean collective bargaining coverage calculated for all years in which country is included in the sample. All countries in sample with at least three waves of earnings data are included (see Annex A for full list).

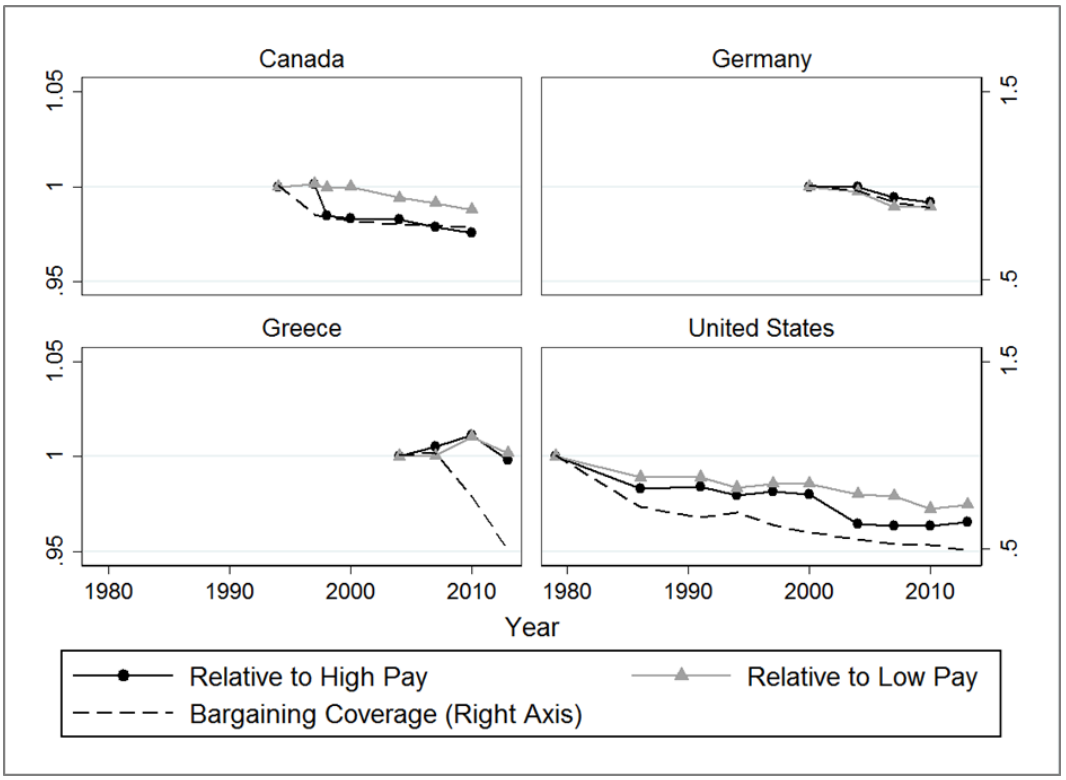
In countries that tend to have higher levels of bargaining coverage, do we see that high RTI occupations have experienced higher relative wage growth? Figure 4.1. presents a pair of scatterplots that help to answer this question. On the X-axis is the mean level of bargaining coverage within a country across all years for which earnings data are available. On the Y-axis is the wage growth of high RTI occupations relative to low pay occupations (left panel) and high pay occupations (right panel) for each country. In the left panel, for example, we see that only in France and Switzerland did high RTI occupations

experience more favourable wage growth relative to low pay occupations among the countries and years examined. In both panels, we see the anticipated positive correlation between levels of bargaining coverage and relative wage growth of high RTI occupations. In the United States and Canada, for example, comparatively low levels of bargaining coverage go along with weak relative wage growth for high RTI jobs. In France, conversely, high levels of bargaining coverage coincide with greater relative wage growth of high RTI occupations. Denmark, however, is among the notable exceptions in the figure. Despite the country's high levels of bargaining coverage (higher than 80% during the years examined), high RTI occupations still saw declining earnings relative to both low pay and high pay occupations.

Do these relationships tend to hold when we examine the within-country relationship between bargaining coverage and relative wage growth? Figures 4.2. through 4.4. present the results for each country. As my estimation strategy measures how within-country changes in bargaining coverage affects relative wage growth of high RTI occupations, I segment the descriptive figures into three groups, based on the direction and extent of changes in bargaining coverage for each country. Figure 4.2. features countries experiencing a decline in levels of bargaining coverage from first to final year, while Figure 4.3. features countries experiencing little to no variation over time, and Figure 4.4. features the countries experiencing (very small) increases in levels of bargaining coverage (see Annex A for more details on trends in bargaining coverage by country). Each figure features three lines: (1) indexed change in levels of bargaining coverage within the country, as well as the indexed wage growth of high RTI occupations relative to (2) low pay occupations and relative to (3) high pay occupations.

Figure 4.2. Indexed wage growth of high RTI occupations relative to low pay and high pay occupations

(Countries experiencing decline in collective bargaining coverage)

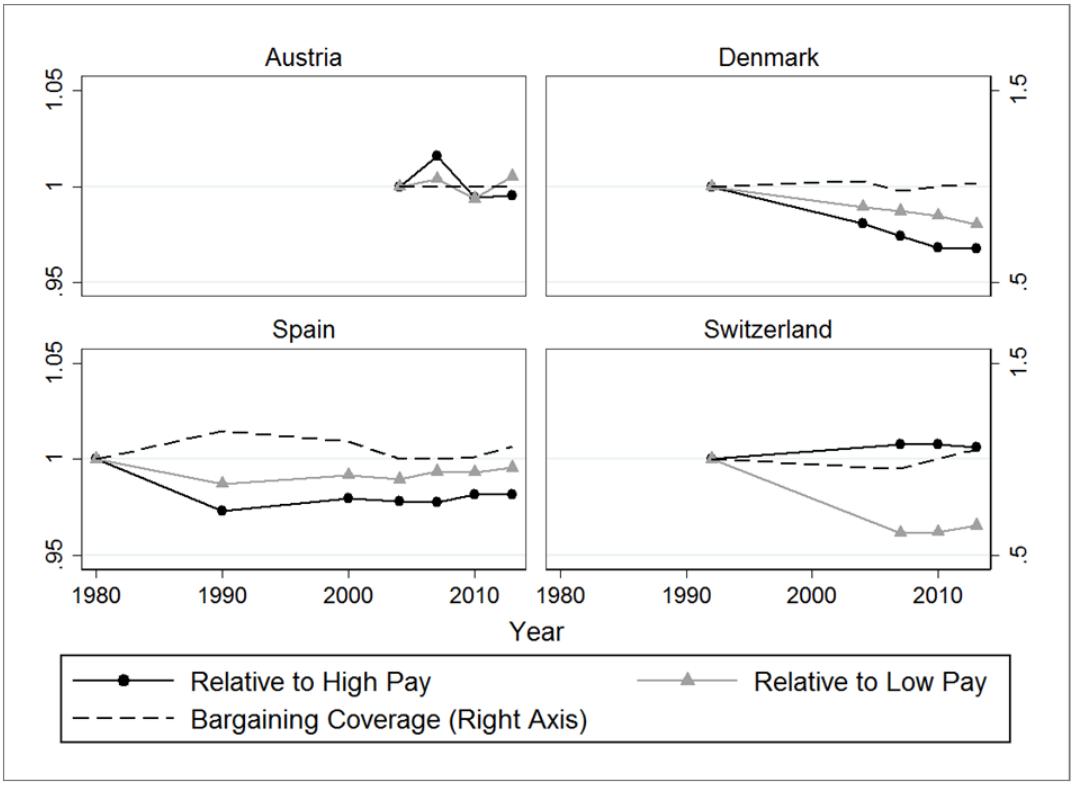


Note: Data via LIS. Countries with fewer than three years of data excluded. High routine task-intensive (RTI) occupations are those in top one-third of country-specific routine task intensity distribution. Low RTI occupations are in split into low-pay (below median) and high-pay (above median) occupations.

Figure 4.2. plots the relationships for Canada, Germany, Greece, and the United States. As the downward sloping dashed line indicates, levels of collective bargaining coverage have declined in each of these countries during the years examined. In Canada, Germany, and the United States, we can see that the earnings of high RTI occupations have declined relative to low pay and high pay occupations from their first to final years within the sample. In Greece, levels of bargaining coverage plummet during the recession and concurrent labour market reforms, though we see no meaningful difference in wage growth between occupation types. Except for Greece, the countries presented align with the hypotheses presented: declining levels of bargaining coverage are associated with less favourable wage growth for high RTI jobs.

Figure 4.3. Indexed wage growth of high RTI occupations relative to low pay and high pay occupations

(Countries experiencing little to no change in collective bargaining coverage)

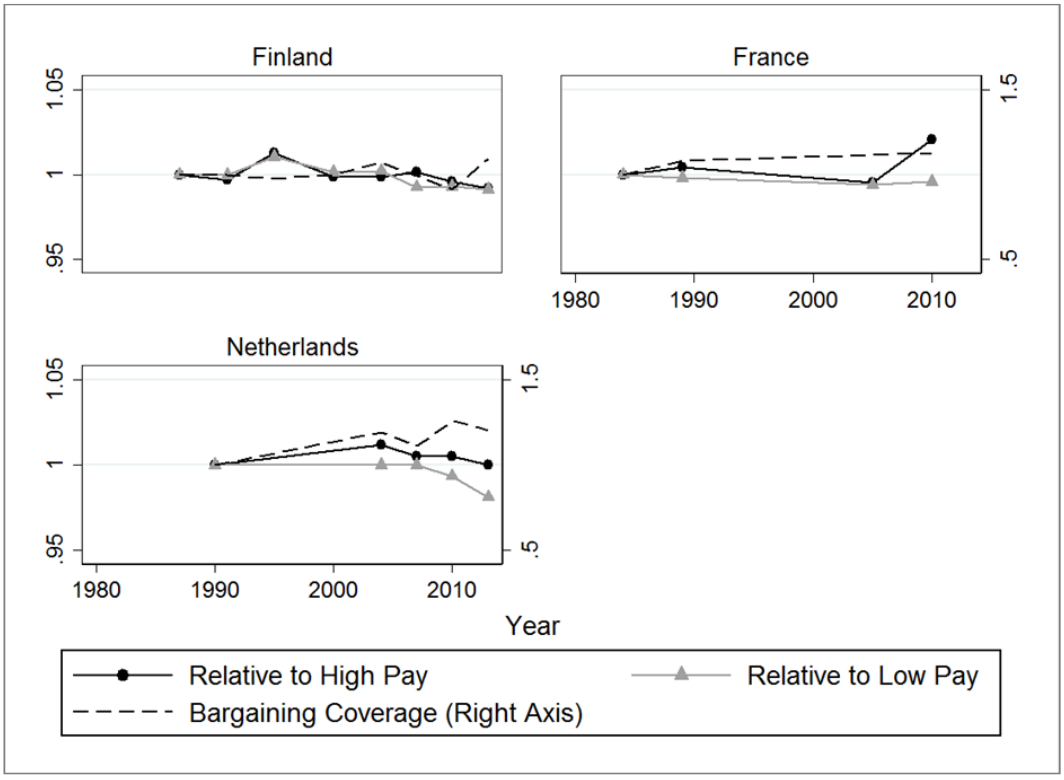


Note: Data via LIS. Countries with fewer than three years of data excluded. High routine task-intensive (RTI) occupations are those in top one-third of country-specific routine task intensity distribution. Low RTI occupations are in split into low-pay (below median) and high-pay (above median) occupations.

Figure 4.3. presents the same findings for four countries – Austria, Denmark, Spain, and Switzerland – that experienced little to no change in levels of bargaining coverage. In Austria and Spain, we see that high RTI occupations have experienced wage growth on par with low pay occupations, consistent with expectations. Just as in the cross-sectional focus of Figure 4.1., however, the case of Denmark contradicts the study's hypothesis. Despite relatively stable levels of bargaining coverage, high RTI occupations experience consistent decline relative to low pay and high pay occupations. In Switzerland, meanwhile, high RTI occupations experience slower wage growth relative to low pay occupations from the early 1990s to 2007, but then make up some ground in recent years when bargaining coverage increases.

Figure 4.4. Indexed wage growth of high RTI occupations relative to low pay and high pay occupations

(Countries experiencing small increases in levels of bargaining coverage)



Note: Data via LIS. Countries with fewer than three years of data excluded. High routine task-intensive (RTI) occupations are those in top one-third of country-specific routine task intensity distribution. Low RTI occupations are in split into low-pay (below median) and high-pay (above median) occupations.

Finally, Figure 4.4. presents the findings for the countries experiencing small increases in bargaining coverage. In the Netherlands, Finland, and France, high RTI occupations appear to experience wage growth on par with low pay and high pay occupations. In the Netherlands, however, the automatable jobs see a slight decline in relative earnings from 2010 to 2013, in line with a slight decline in bargaining coverage.

On balance, the descriptive portraits provide some evidence that high RTI occupations may experience declining relative wage growth in countries which have seen declining levels of collective bargaining coverage. The experience of Denmark and Greece, however, provide evidence counter to expectations. Of course, there are a number of factors driving differences in occupational wage growth across place and time, and we cannot derive from these figures that changes in bargaining coverage are a central source of variation. To further investigate the role of bargaining coverage on occupational wage trends, I now turn toward the formal estimates of the hypotheses presented before.

Table 4.1. Estimations of Wage Trends of Low RTI (Low Pay and High Pay) Occupations Relative to High RTI Occupations

	15 OECD Member States		50 United States	
	A1	A2	B1	B2
Low Pay (Reference: High RTI)	-.126*** (-4.84)	-.160*** (-8.15)	-.133*** (-17.4)	-.102*** (-9.9)
High Pay (Reference: High RTI)	.206** (3.74)	.215** (3.84)	.284*** (46.8)	.315*** (36.5)
Low Pay # Year (Linear)	.004* (2.13)	.007** (4.73)	-.000 (-0.76)	-.002*** (-4.98)
High Pay # Year (Linear)	.003 (0.89)	.006** (3.84)	-.000 (4.03)	-.002*** (0.56)
Low Pay # Bargaining Coverage		.042 (1.83)		-.041*** (-3.84)
High Pay # Bargaining Coverage		-.078* (-2.44)		-.039*** (-6.09)
Bargaining Coverage # Year (Linear)		.006*** (3.31)		-.001** (-3.09)
Low Pay # Bargaining Coverage # Year (Linear)		-.004* (-2.37)		-.003*** (-4.61)
High Pay # Bargaining Coverage # Year (Linear)		.000 (0.43)		-.001** (-3.18)
Observations	1,398,417	1,398,417	1,905,150	1,905,150

Note: All models include individual-level controls (age, education, sex) and state-industry-year fixed effects. Low pay refers to low RTI occupations with median income below the country-median, and high pay above the median. t statistics in parentheses. Standardised coefficients presented for collective bargaining coverage. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4.1. presents the results of Equations (4) and (5) for both the cross-national and cross-state samples. Columns A1 and B1 show the conditional wage trends of low pay and high pay occupations relative to high RTI occupations. In Column A1, the significant interaction term of low pay and the linear time-trend ("year") indicates that the earnings of low pay occupations have, on average, grown at a faster rate than high RTI occupations among country-years in the sample (net of the controls for demographic characteristics). We do not observe the same pattern, however, for high RTI occupations relative to high pay occupations. In the cross-state United States sample (B1), the insignificant interactions indicate that high RTI occupations have not, on average, grown at a different rate relative to low pay and high pay occupations, net of the controls. The insignificant effect for the low pay wage growth relative to high RTI occupations, however, appears to be due to differing trends before and after 2000: when the model is restricted to the years 1984 to 1999, low pay occupations grow at a faster (and statistically significant) rate relative to high RTI occupations, but from 2000 to 2015, high RTI occupations grow at a faster rate than low-pay occupations. This is consistent with the findings in Mishel, Schmitt, and Shierholz (2013).

The time-trend findings suggest that wage polarisation is certainly not the norm across the United States or OECD Member States. If it were, we would see high pay and low pay occupations both growing faster than the high RTI occupations (positive and significant effects). Can variation in changes of bargaining coverage help to explain differential occupational growth rates across countries? Columns A2 and B2 present the results of the three-way interactions.

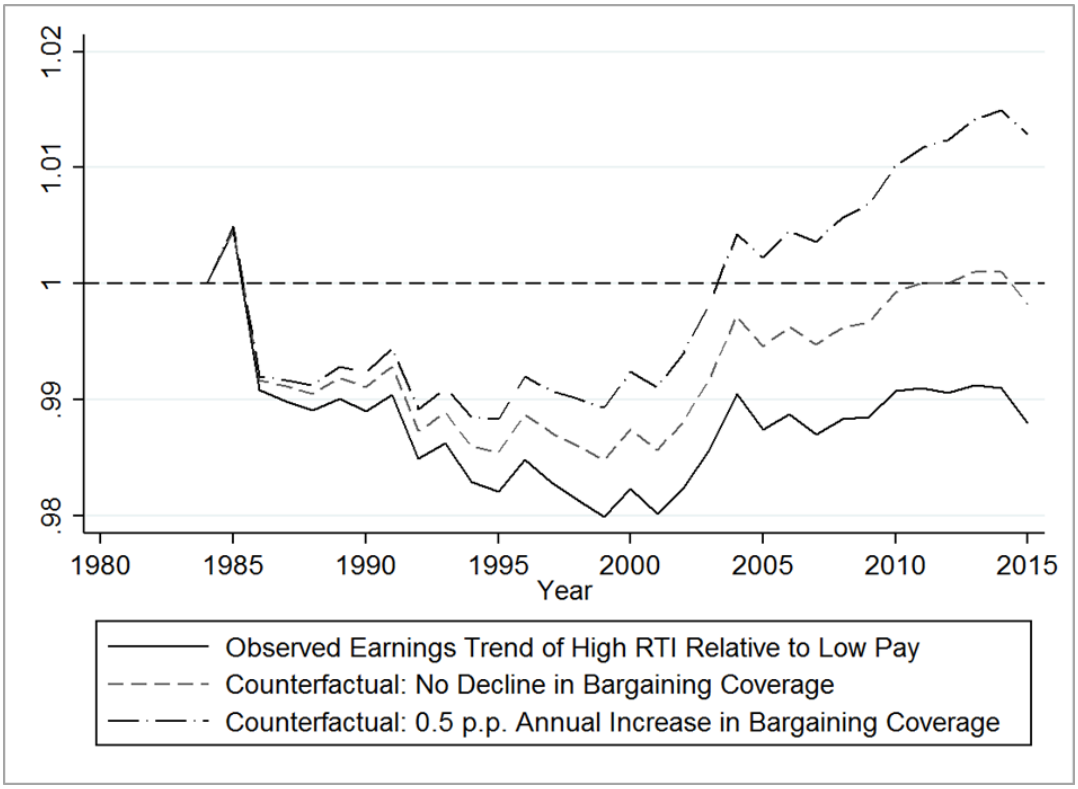
Across the OECD Member States (A2), we see that rising bargaining coverage within a country is associated with reduced wage growth for low pay occupations relative to high RTI jobs (see the negative and significant slope for the 'low pay', year, and bargaining coverage interaction in A2). In other words, declining bargaining coverage is associated with declining wage gains for automatable occupations (the reference group) relative to low pay occupations. Specifically, a one standard deviation decrease in levels of collective bargaining coverage (31 percentage points, or falling from the level in Finland down to the level of Germany in 2013) is associated with an annual 0.4% decline, on average, of wage growth in high RTI occupations relative to low pay occupations.

We see similar patterns in the United States sample (B2). Recall that in this cross-state sample, bargaining coverage is measured at the state-industry level rather than the country level. As in the cross-national sample, we see that declining bargaining coverage is associated with declining wage gains for high RTI occupations relative to low pay occupations relative (see the negative and significant slope for the 'low pay', year, and bargaining coverage interaction in B2). Again, this is consistent with this study's primary hypothesis. Here, we also see that declining bargaining coverage is associated with declining wage gains for *high pay* occupations relative to high RTI occupations. In other words, rising levels of union coverage among high RTI occupations in United States industries would contribute to higher wage gains of automatable occupations relative to low pay *and* high pay occupations. The observed decline in union coverage from the 1980s onward, then, has likely contributed to the observed decline in relative wage growth of high RTI occupations in the United States.

I now present a counterfactual exercise to further contextualise the findings from Table 4.1. In Figure 4.5., I display the estimated evolution of the earnings of high RTI occupations relative to low pay occupations in the United States in two alternative scenarios: first, if the United States had experienced no decline in bargaining coverage among high RTI occupations from 1984 onward and, second, if high RTI occupations in the United States had experienced a 0.5 percentage point annual *increase* in union membership from 1984 onward.[11] These counterfactual estimates are produced using the cross-state sample (Table 4.1., Model B2), but with year dummies rather than linear time trends in the interaction to account for any non-linear, year-to-year differences in relative wage growth rates.

[11] An annual increase of 0.5 percentage points would result a rise in union membership from 19.2% in 1984 to 32.2% in 2015. This rate of growth is selected arbitrarily, but is meant to provide an illustrative example of the estimated effect of a modest rise in union membership on relative wage trends.

Figure 4.5. Counterfactual wage growth of high RTI occupations relative to low pay occupations in United States if bargaining coverage had increased or remained stable since 1984



Note: Percent change in log annual earnings of high RTI occupations relative to low pay occupations. No decline in bargaining coverage (counterfactual scenario) equates to United States remaining at 1984 levels (mean of 19.2%) across all years. Predictions taken from Table 4.1., B2 with addition of 'occupation group'-year dummies.

The solid black line in Figure 4.5. represents the observed indexed wage growth of high RTI occupations relative to low pay occupations from 1984 onward.[12] The darker dashed line represents the counterfactual wage trends if levels of union coverage (again, similar to bargaining coverage in the United States) among high RTI occupations had not declined from their 1984 levels. Rather than experiencing a decline in earnings relative to low pay occupations, workers in high RTI jobs would have, on average, experienced wage growth roughly even with that of low pay occupations from 1984 to 2015.

Had union membership increased at a rate of half a percentage point per year from 1984 onward, the estimates suggest that high RTI occupations might have experienced

[12] The relative wage trends of high RTI occupations in the United States differ in Figure 4.5. compared to those presented before in Figure 4.2. This is for two primary reasons: Figure 4.2. presented results for all countries using the two-digit occupation codes in LIS, while Figure 4.5. uses the three-digit occupation codes available in the CPS MORG (see *Data & Methods* section or Annex C). Second, the starting points for the wage trends are different. In Figure 4.2., wage trends are indexed to the (higher) values of 1979 (the first year available in the LIS analysis), whereas Figure 4.5. indexes wage trends to (lower) values in 1984 (the first year available in the CPS MORG analysis).

greater wage growth relative to low pay occupations (around 1.5% higher relative wage growth, on average, rather than 1.1% lower relative wage growth). Additionally, the estimates suggest that the observed pattern of occupational wage polarisation between 1990 and 2000 (in which earnings of high RTI occupations were declining relative to low pay occupations) might not have occurred had union membership increased at this rate. While this finding does not suggest that declining union coverage caused the decade of occupational wage polarisation in the United States, it nonetheless suggests that the extent of wage polarisation might have been reduced had union coverage not declined.

In Annex E, I present figures displaying the absolute rather than relative counterfactual wage trends for low pay and high RTI occupations. These counterfactuals show that an increase in union membership among high RTI occupations is estimated to increase real wage growth of high RTI occupations while dampening the observed wage growth of low pay occupations.

4.1. Mechanisms of Relative Wage Growth

How is it that declining bargaining coverage contributes to declining relative wage growth for automatable occupations? Before, I proposed four mechanisms that could drive the observed relationship: (1) changes in bargaining coverage might be *more consequential* for the wages of high RTI occupations, (2) might *decline at a faster rate* among high RTI occupations when bargaining coverage at the national level declines, or might generate (3) an *employment effect* or (4) *investment effect*.

As discussed in the *Hypotheses & Mechanisms* section, available evidence offers some support for the first two claims. As demonstrated in Annex F, I find that, within the United States, the relative wage premium for working in an industry with high levels of bargaining coverage is consistently higher for automatable occupations relative to other occupation types. Given this, declines in bargaining coverage at the national level, even if split evenly among occupation types, would be *more consequential* to changes in the wages of automatable occupations. If that were to hold across the 15 countries in the cross-national sample (untestable with available data), it would plausibly help to explain why declining bargaining appears to adversely affect the wage growth of automatable occupations. Similarly, available evidence suggests that when union density at the national level declines, it tends to fall more steeply for automatable occupations (again, see Annex F). This holds for changes in bargaining coverage within the United States and changes in union density across many Member States of the European Union. If this pattern were to also apply to changes in bargaining coverage across the 15 advanced economies in the cross-national sample (not directly testable with available data), then it could, again, plausibly explain why declines in bargaining coverage contribute to declining relative wage gains for automatable jobs.

I now turn toward estimating the third and fourth mechanisms proposed – an employment effect or investment effect – applying Equations (6) and (7) as described in the prior section.

Table 4.2. Logistic Regression Estimates of Working in High RTI Occupation Relative to Low RTI (Low Pay or High Pay) Occupation

	15 OECD Member States		50 United States	
	A1	A2	B1	B2
Bargaining Coverage	.222	.140	-.020	-.010
	(0.40)	(-0.08)	(-1.46)	(-0.96)
Bargaining Coverage # Year (Linear)		.012		-.003***
		(0.16)		(8.40)
State-Industry FE	X		X	
Year FE	X		X	
State-Industry-Year FE		X		X
Observations	1,398,414	1,398,414	1,923,985	1,923,985

Note: Dependent variable: binary indicator of whether employed adult works in high RTI occupation. All models include individual-level controls (age, education, sex). t statistics in parentheses. Standardised coefficients presented for collective bargaining coverage. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

In Table 4.2., I present the results of the employment effect hypothesis. In Columns A1 and B1, I first assess the relationship between changes in bargaining coverage and the employment share of automatable occupations within a country. For the cross-national sample of 15 OECD Member States (A1), the effect of within-country variation in bargaining coverage on employment shares of high RTI occupations is positive, but statistically insignificant. For the 50 United States (B1), the effect is negative, but likewise insignificant. We cannot conclude, then, that changes in bargaining coverage within a country (or state-industry within the United States) have a direct effect on employment shares of high RTI occupations. It may be the case, however, that the effect of within-county variation in bargaining coverage has intensified over time as demand for routine tasks has declined. Columns A2 and B2 add the interaction of bargaining coverage and the linear time trend (as well as the state-industry-year fixed effects). If the interaction were to be negative and significant, this would suggest that the effect of rising bargaining coverage has an increasingly negative effect (compared to its baseline value) on the share of high RTI occupations within the country. In other words, employers in contexts of rising bargaining coverage might compensate for higher wage growth with reduced employment of automatable jobs.

In the cross-national sample (A2), the evidence does not support this conclusion. The interaction is positive and statistically insignificant. In the United States sample (B2), however, we do find evidence of a negative employment effect. The interaction term suggests that with each additional year, the effect of rising bargaining coverage among automatable occupations has an increasingly negative effect on employment shares of automatable jobs. Put differently, declining bargaining coverage among high RTI occupations appears to be increasingly associated with the preservation of employment shares of high RTI occupations within the given state and industry. This finding is consistent with the employment effect hypothesis, as well as prior literature on the dualisation or insider/outsider effect of unionisation.

Might a country's initial level of bargaining coverage affect whether a change in coverage contributes to a negative employment effect? In further assessment of the findings (not presented but available upon request), I re-estimate the results of Table 4.2., Column A2 after splitting the cross-national LIS sample into two groups: countries with bargaining coverage below 50% during their first year in the analysis (US, CA, IE, CH), and countries with bargaining coverage above 50% during their first year in the analysis (LU, DE, NL,

DK, FI, FR, ES, IS, BE, AT). In the low-coverage sample, the interaction of bargaining coverage and the linear time trend is negative and significant (a slope of -.18 with robust standard errors of .01), similar to the results found in the United States sample. In the high-coverage sample, however, the interaction is again positive and insignificant. This suggests that the negative employment effect is perhaps limited to countries which have traditionally featured weaker bargaining institutions.

Keep in mind that each of these analyses excludes jobless adults and, thus, can only provide a partial portrait of employment consequences. Despite this caveat, the results suggest that a negative employment effect is, indeed, a possible mechanism by which increases in bargaining coverage can be associated with increasing relative wage growth for high RTI occupations, at least among countries with traditionally weak bargaining institutions.

Table 4.3. Effect of Bargaining Coverage and Share of RTI Occupations on Industry-Level ICT and Non-ICT Capital Investment

(*15 OECD Member States)*

	ICT Investment		Non-ICT Investment	
	(1)	(2)	(1)	(2)
Bargaining Coverage # Year	.000 (0.04)	.000 (0.97)	-.00 (-0.11)	.001* (2.30)
High RTI Share # Year		-.03 (-0.25)		-.62 (2.08)
Bargaining Coverage # High RTI Share		.02 (0.01)		14.0 (2.01)
High RTI Share # Bargaining Coverage # Year		-.000 (-0.00)		-.007 (-2.17)
Observations	321	321	321	321

Note: Country-Industry and Year panel data. All models include country-industry and year fixed effects. Results are robust to single-year lag specification and population-weighted country-industries. (Non-)ICT investment represents the contribution of (non-)ICT capital services to value added growth at the country and industry level (via EU KLEMS). Sample includes industries in AT, BE, DK, FI, FR, DE, LU, NL, ES, US – all countries from LIS sample for which EU KLEMs data is available. t statistics in parentheses. Standardised coefficients presented for country-level institutions. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Finally, Table 4.3. tests the investment effect hypothesis. As detailed before, another mechanism by which higher bargaining coverage within a country can increase relative wage growth of high RTI occupations is through smaller investments into labour-replacing technologies. This would have the effect of mitigating the shift in demand away from routine tasks. Model 1 in Table 4.3. explores whether rising bargaining coverage contributes to a decline in investment in ICT capital over time. The effect is close to zero and insignificant. Model 2 then adds the triple interaction with bargaining coverage. If the interaction were significant and negative, this would suggest that in industries with greater shares of automatable occupations, ICT investment declines over time if collective bargaining coverage is rising. Instead, the effect is again close to zero and insignificant. Investigating the effect of bargaining coverage and share of high RTI occupations on industry-level non-ICT investment (Models 3 and 4) similarly provide no significant or substantial results. As a result, the evidence does not support the investment hypothesis. In other words, the ability of higher bargaining coverage within a country to contribute to higher relative earnings of automatable occupations does not appear to be significantly related to within-industry declines in capital investment.

5. Discussion

This paper set out to investigate how collective bargaining and union coverage affect the relative wage growth of highly automatable occupations. While prior analyses of routine-biased technological change (RBTC) have demonstrated that declining demand for routine tasks negatively affects the wage growth of high routine task-intensive (RTI) occupations, few studies have worked to understand how these processes vary across institutional context. This paper finds evidence across two separate samples that declining levels of collective bargaining coverage within a country contribute to declining relative wage growth of high RTI occupations. In other words, collective bargaining appears to shape the relationship between the forces of automation and the relative wage growth of automatable jobs.

Rather than focusing on occupational wage trends in a single polity, this paper measured the effect of changes in collective bargaining coverage on differential wage growth of occupations across 15 countries. Using LIS micro-data spanning 1.4 million workers from 1979 onward, I found that a one standard deviation decline in collective bargaining coverage is associated with a 0.4% decline in the wage growth of high RTI occupations relative to wage growth of low RTI, low pay occupations. To provide a sensitivity check and to address a possible mechanical relationship between automation and bargaining coverage, I also performed the estimates on a second sample of 1.9 million employed adults within the United States. Use of the United States microdata allowed for measurement of bargaining coverage among high RTI occupations at the state and industry level, rather than a single measure at the national level. Despite relatively low levels of unionisation across the United States, variation in changes of coverage rates across states and industries corroborated the results of the cross-national analysis. Even when staying within the borders of the United States, the country most often examined in analyses of RBTC, regional differences in labour market institutions can help to explain differential patterns of wage growth among automatable occupations. Indeed, a counterfactual simulation of occupational wage growth in the United States suggests that the earnings of high RTI occupations might have experienced wage growth on par with that of low pay occupations between 1984 and 2015 had bargaining coverage not declined. In an unlikely scenario in which bargaining coverage in the United States were to have increased at an annual rate of 0.5 percentage points from 1984 onward, occupational wage polarisation might not have occurred in the 1990s.

Of the four mechanisms proposed to explain why declining bargaining coverage leads to declining relative wage growth for automatable occupations, three stood out to hold more empirical weight. First, I found that, at least within the United States, bargaining coverage appears to be *more consequential* for the earnings of high RTI occupations relative to low RTI occupations. The relative wage premium for working in a state and industry with higher levels of unionisation is consistently greater for automatable occupations, with little variation from 1984 to 2015. Thus, declines in bargaining coverage would, all else constant, contribute to declining relative earnings for automatable occupations, helping to explain this study's primary results. More research is needed, however, on whether this pattern holds across the 15 advanced economies featured in the cross-national sample.

A second plausible mechanism is that bargaining coverage *declines at a faster rate* among high RTI occupations when bargaining coverage at the national level declines. This is more consequential for the cross-national analysis within this paper, in which changes in bargaining coverage could only be measured at the national level. Using data on changes in union coverage (not perfectly analogous to changes in bargaining coverage) from the European Social Survey, I found evidence that unionisation has, indeed, declined at a faster rate among high RTI occupations. If this were to also apply to changes in bargaining coverage, it would help to explain why declining bargaining coverage at the national level appears to contribute to declining relative wage growth for high RTI jobs.

Third, I found that a negative employment effect may help to explain how rising bargaining coverage can contribute to rising relative wage growth for high RTI occupation in a context of declining demand for routine tasks. Specifically, the results showed that the effect of rising bargaining coverage has an increasingly negative effect on employment shares of automatable jobs in countries with traditionally weak collective bargaining institutions. Given this, it may be the case the automatable workers covered under a union or bargaining contract can achieve higher relative wage increases, but at the cost of reduced employment for non-covered workers who might otherwise work in the same occupations. Future analyses of a possible employment effect, however, should take into account involuntarily jobless adults, perhaps using panel data or repeated cross-sectional data with detailed information on employment histories.

Finally, I also investigated a possible *investment effect* mechanism, in which rising levels of bargaining coverage within a country might discourage employers from investing in new technologies, leading to an effective slowdown in task price adjustments. The evidence presented, however, did not support this hypothesis. Again, future research should continue investigating this question using a more precise identification strategy than is allowed with country-level indicators of collective bargaining institutions.

Several other limitations should also be acknowledged. First, the use of annual earnings in the cross-national analysis, rather than hourly wages, is a slight deviation from prior analyses of RBTC. However, a lack of information on hourly wages across a substantive number of country-years in the LIS data leaves little choice. Still, sensitivity checks reveal no substantive differences in the results when re-estimating the analyses with hourly wage data on the reduced sample in the cross-national analysis, or in the cross-state sample in the United States (see Table A F.1.). Second, and similarly, the integration of the RTI data into LIS is only available for the two-digit occupation codes, rather than the more-precise three- or four-digit codes. While not ideal, robustness checks again suggest that the difference may not be consequential: whether running the cross-state sample on two-digit or three-digit occupation codes, the results produce substantively similar findings (Table A F.2.). Finally, this paper focuses exclusively on wage differences *between* occupations. However, Mishel, Schmitt and Shierholz (2013) find, within the United States, that *within*-occupation wage differences are increasingly consequential in shaping the overall wage distribution. Future research can build on the analyses presented here to more fully investigate how automation, and its interaction with labour market institutions, affects broader trends in wage inequality.

More generally, researchers should continue to place analyses of automation and occupational change into institutional context. As this study has demonstrated, the declining strength of organised labour appears to adversely affect the wage growth of automatable occupations relative to less routine occupations.

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Annex A. Countries included in study and trends in strength of bargaining institutions by country

Table A A.1. Countries and years included in cross-national sample

	Country	Years	N
1	Austria	2004, 2007, 2010, 2013	24,481
2	Belgium	1995, 1997, 2000	8,972
3	Canada	1994, 1997, 1998, 2000, 2004, 2007, 2010	199,438
4	Denmark	1992, 2004, 2007, 2010, 2013	359,762
5	Finland	1987, 1991, 1995, 2000, 2004, 2007, 2010, 2013	102,850
6	France	1984, 1989, 1994, 2000, 2005, 2010	65,024
7	Germany	2000, 2004, 2007, 2010, 2013	83,910
8	Greece	2004, 2007, 2010, 2013	19,561
9	Iceland	2004, 2007, 2010	14,095
10	Ireland	1994, 1995, 1996, 2000, 2004, 2007, 2010	24,430
11	Luxembourg	1997, 2000, 2004, 2007, 2010, 2013	22,299
12	Netherlands	1990, 1993, 1999, 2004, 2007, 2010, 2013	64,745
13	Spain	1980, 1990, 1995, 2000, 2004, 2007, 2010, 2013	85,884
14	Switzerland	1992, 2007, 2010, 2013	30,813
15	United States	1979, 1986, 1991, 1994, 1997, 2000, 2004, 2007, 2010, 2013	776,311

Table A A.2. Trends in strength of bargaining institutions by country

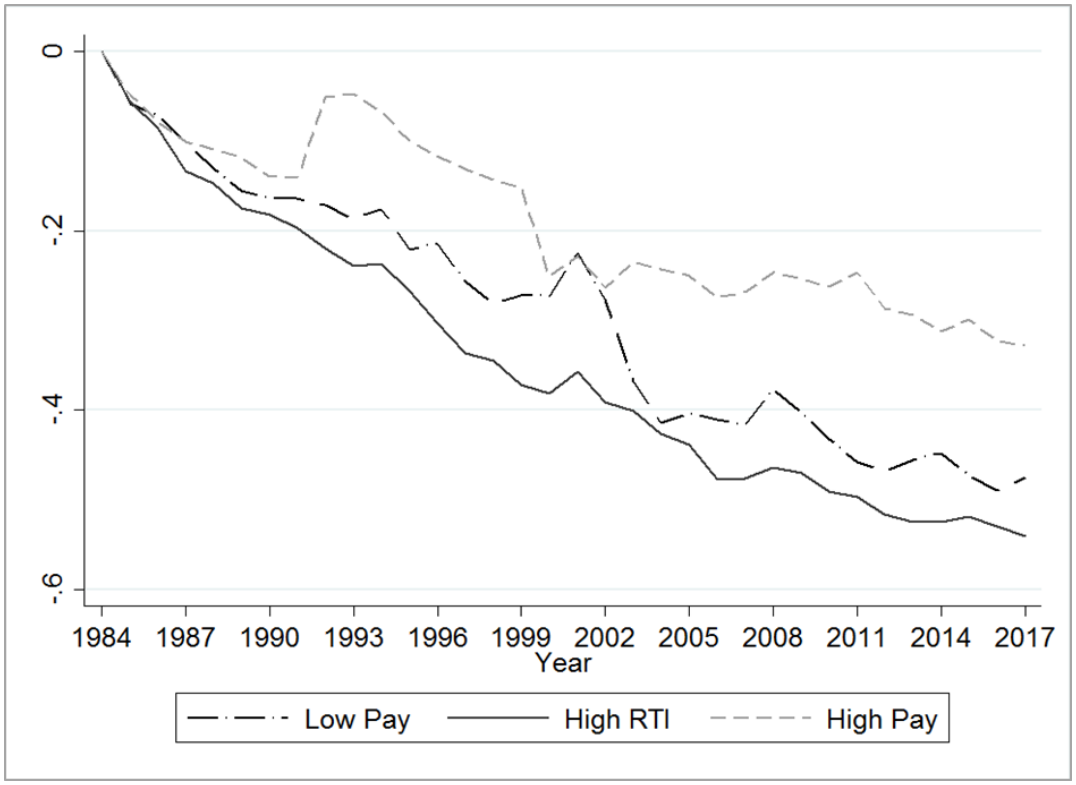
Country	Bargaining Coverage	Union Density	Time Span
Austria		-6.0	2004 - 2013
		(-18%)	
Belgium		3.4	1995 – 2000
		(6%)	
Canada	-7.4	-3.6	1994 – 2010
	(-20%)	*(-11%)*	
Denmark	1.2	-7.8	1992 – 2013
	(1%)	*(-10%)*	
Finland	16.0	.	1987 – 2013
	(21%)	.	
France	21.7	-14.4	1978 – 2010
	(29%)	*(-65%)*	
Germany	-10.2	-6.9	2000 – 2013
	(-15%)	*(-28%)*	
Greece	-18.0		2004 – 2013
	(-22%)		
Iceland	.	-12.0	2004 – 2010
	.	*(-12%)*	
Ireland		-12.1	1994 – 2010
		(-26%)	
Luxembourg	-1.0	-7.1	1997 – 2013
	(-2%)	*(-17%)*	
Netherlands	13.7	-6.3	1990 – 2013
	(19%)	*(-26%)*	
Spain	1.6	3.4	1980 – 2013
	(2%)	*(25%)*	
Switzerland	-1.6	-5.4	1992 – 2013
	(-3%)	*(-24%)*	
United States	-14.1	-12.4	1979 - 2013
	(-54%)	*(-53%)*	
Mean	**1.2**	**-5.0**	
	(-2.8%)	***(-12.6%)***	

Note: Absolute changes presented first with relative changes in parentheses and italics. Dots represent no change during the years of analysis. Data source: ICTWSS Database (Visser 2015).

Annex B. Change in Union Coverage by Occupation Type

Figure A B.1. Percent Change in Union Coverage by Year & Occupation Type

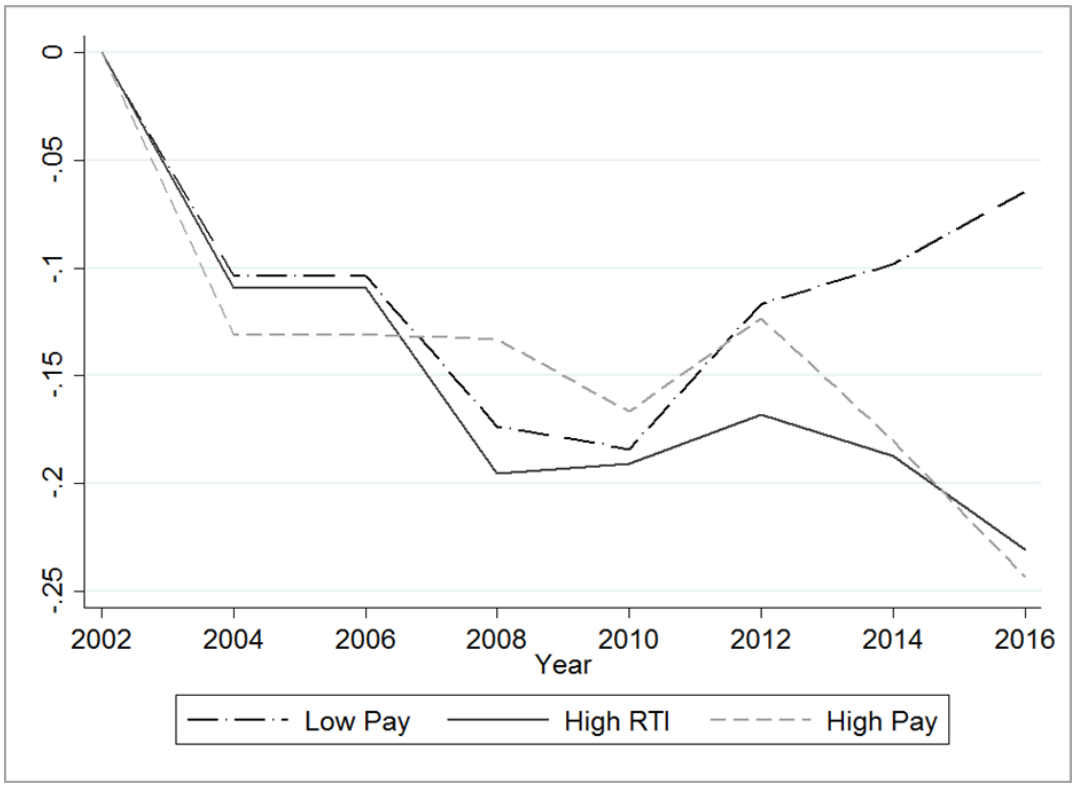
(United States)



Note: Data source: CPS Merged Outgoing Rotation Groups. Mean weighted value of current union membership by occupation type among the 50 United States. Three-digit occupations codes used to separate occupations into groups, corresponding with occupation types identified in cross-state (CPS) sample.

Figure A B.2. Percent Change in Union Coverage by Year & Occupation Type

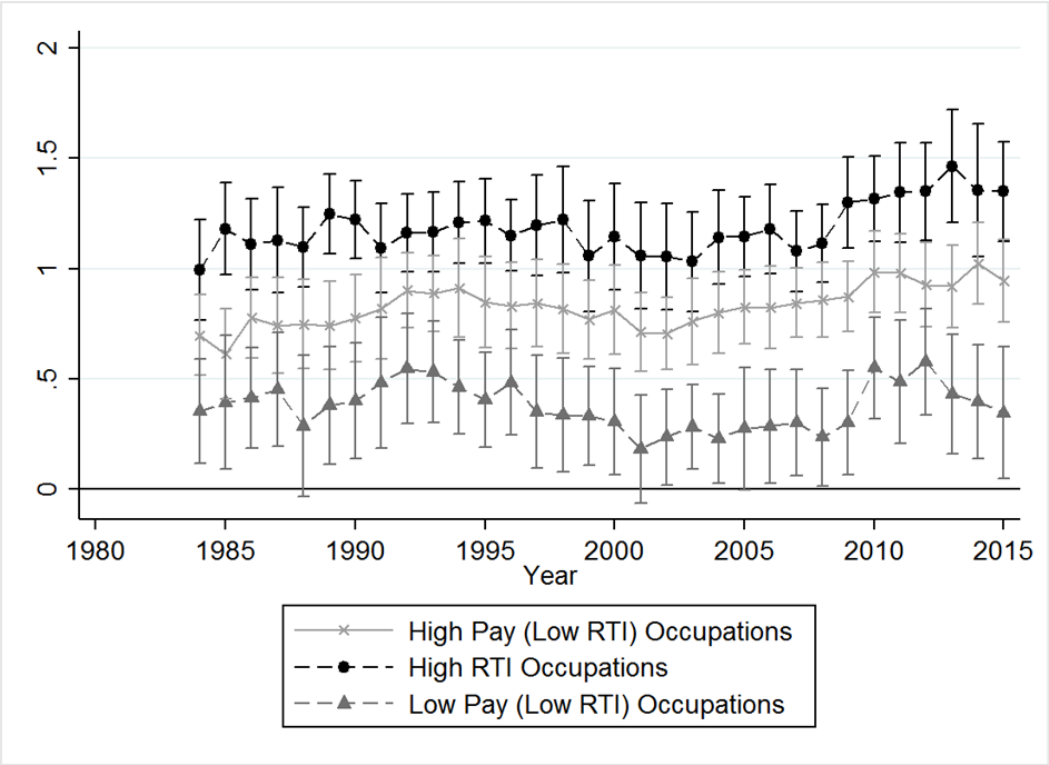
(EU Member States)



Note: Data source: European Social Survey (ESS, 2002 – 2016). Mean weighted value of current union membership by occupation type among the 22 EU Member States included in all waves of ESS data: AT, BE, CH, CZ, DE, DK, ES, FI, FR, GR, HU, IE, IL, IT, LU, NL, NO, PL, PT, SE, SI, UK. Two-digit ISCO codes used to separate occupations into groups, corresponding with occupation types identified in LIS (see Table 4.1.).

Figure A B.3. Bargaining Premium in the United States: Relative Effect of State-Industry Union Coverage on Log Earnings of Low Pay, High Pay, and High RTI Occupations in the United States

(50 United States)



Note: Y-Axis: Relative increase to mean log earnings with 10 percentage point increase in state-industry level of union coverage by year. For each occupation type, I regress log (wage) on union-year interaction, controlling for age, education, and sex, and include state-industry-year fixed effects. Figure displays relative increase in counterfactual wage after 10 percentage point increase is estimated.

Annex C. Data Construction for Industry-Level Bargaining Coverage across the United States

Following the approach of Hirsch and MacPherson (2003) and Western and Rosenfeld (2011), I use the Current Population Survey Merged Outgoing Rotation Group (CPS MORG) files to compute union coverage among high RTI occupations in each state and industry coverage. I group industries according to the 9-category ISIC Rev 3.1. codes. As I measure union share among high RTI occupations within each industry in each state, this leads to 459 different measures (9 industries * 51 states, as I include D.C.) I drop individuals in the Armed Forces. To ensure adequate sample sizes across state-industries, I compute three-year averages (n-1, n, n+1) of industry coverage using the recommended earnings weight (EARNWT). I also experiment with top- and bottom-coding the union coverage levels (removing any state-industry cluster with zero or unionisation above the 99th percentile), but this does not affect the findings. The mean industry-level union coverage of high RTI occupations across all years was 12.8%, with a standard deviation of 10.9%. Consistent with national-level union trends, the mean declined from 19.2% in 1984 to 9.9% in 2015. In 2015, the state with the highest share of unionisation among high RTI occupations was New York (a mean of 20.3%), while the state with the lowest was South Carolina (1.4%).

After constructing the state-industry union coverage shares, I merge them into the CPS ASEC files from 1984 to 2015. The CPS ASEC (March dataset) is the dataset most often used in the United States for estimating annual wage and income patterns. The final sample equates around 1.9 million workers.

Annex D. Calculating the Routine Task Intensity (RTI) Index

Following prior literature, I compute indices of routine task intensity (RTI) for each occupation using information on job tasks from the Occupational Information Network database (O*NET). The RTI index assigns values to occupations according to the extent to which they require routine, manual, or abstract tasks. Specifically, Acemoglu and Autor (2011) compute an occupation's RTI as follows:

$$RTI_k = \ln\left(T_k^R\right) - \ln\left(T_k^M\right) - \ln\left(T_k^A\right) \quad (A1)$$

where T_k^R, T_k^M, and T_k^A represent, respectively, the level of routine, manual, and abstract task inputs for an occupation k. Routine tasks consist of repeated sequence of actions and are more easily replaceable through technological innovations. Manual tasks, meanwhile, do not generally follow a predictable sequence and therefore are more resistant to automation. Abstract tasks tend to complement new technologies rather than to be automated. Given this equation, a higher value of RTI_k indicates that an occupation is more 'routine-task intensive' and, thus, can more readily be automated.

Annex E. Predicted Change in Real Log Earnings of High RTI and Low Pay Occupations

Figure A E.1. Counterfactual wage growth of high RTI occupations in United States if bargaining coverage had increased or remained stable since 1984

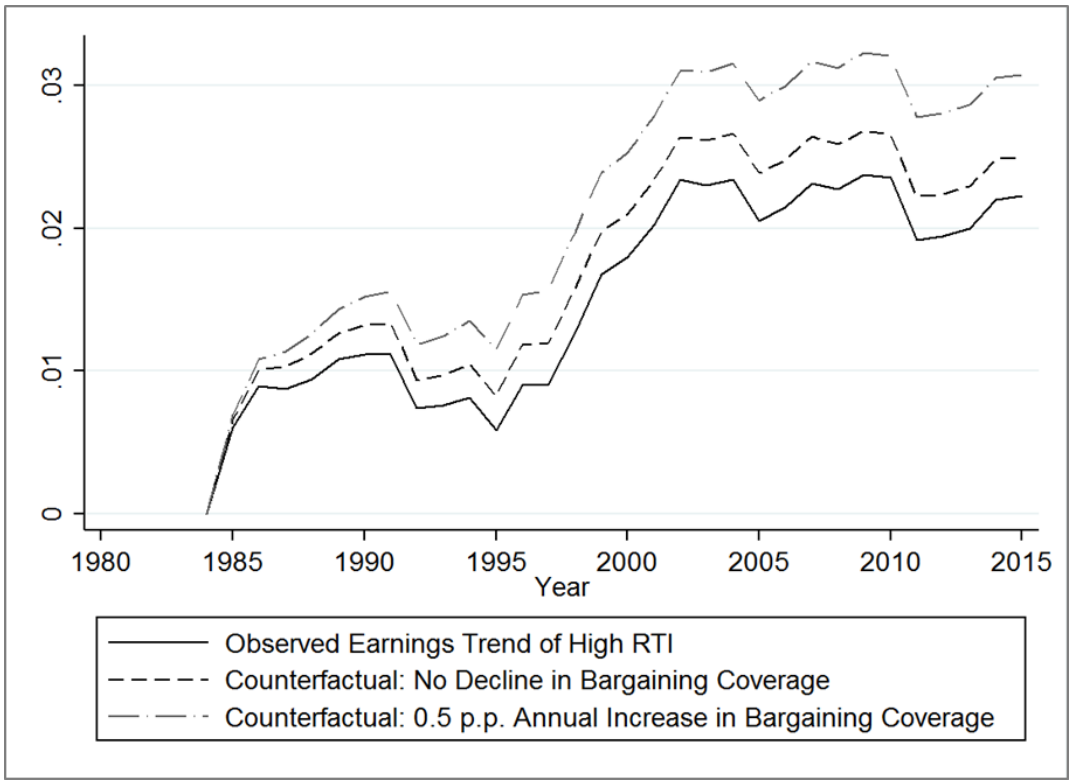
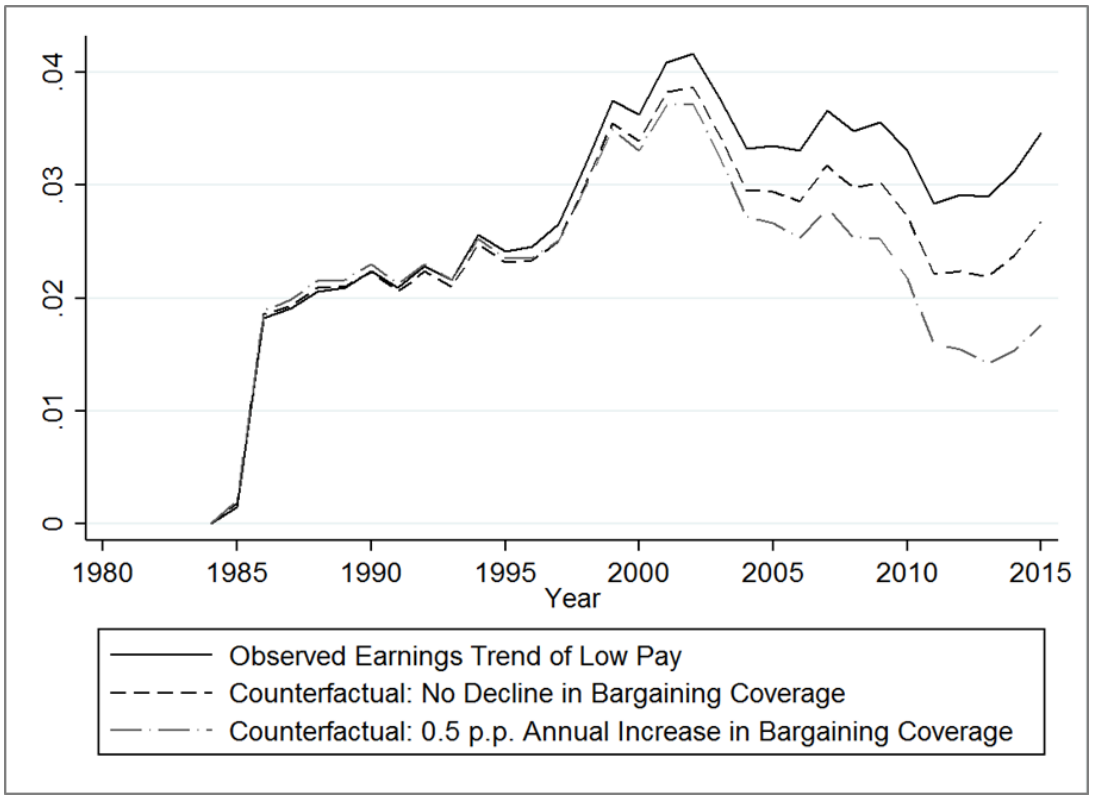


Figure A E.2. Counterfactual wage growth of low pay occupations in United States if bargaining coverage had increased or remained stable since 1984



Annex F. Sensitivity Checks & Alternative Estimates

Table A F.1. Hourly Wages: Estimations of Wage Trends of Low RTI (Low Pay and High Pay) Occupations Relative to High RTI Occupations Using Log Hourly Wages

(United States: 50 States)

	(1)	(2)
Low Pay	-0.14***	-0.12***
	(-19.03)	(-11.29)
High Pay	0.19***	0.20***
	(24.45)	(22.09)
Low Pay # Year (Linear)	-0.000	-0.002***
	(-1.12)	(-4.29)
High Pay # Year (Linear)	-0.000	-0.001***
	(-1.10)	(-6.10)
Bargaining Coverage # Year (Linear)		0.000*
		(2.21)
Low Pay # Bargaining Coverage # Year (Linear)		-0.002***
		(-4.46)
High Pay # Bargaining Coverage # Year (Linear)		-0.001***
		(-4.95)
Observations	1,916,359	1,916,359

Note: All models include individual-level controls (age, education, sex) and state-industry-year fixed effects. Low pay refers to low RTI occupations with average income below the country-wide mean, and high pay above the mean. Interaction of bargaining coverage and low/high pay not displayed for brevity. t statistics in parentheses. Standardised coefficients presented for collective bargaining coverage. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A F.2. Two-Digit Occupation Codes: Estimations of Wage Trends of Low RTI (Low Pay and High Pay) Occupations Relative to High RTI Occupations Using Two-Digit Occupation Codes

(United States: 50 States)

	(1)	(2)
Low Pay	-0.10***	-0.09***
	(-6.61)	(-4.93)
High Pay	0.24***	0.26***
	(41.77)	(33.27)
Low Pay # Year (Linear)	-0.002**	-0.002***
	(-3.64)	(-5.23)
High Pay # Year (Linear)	0.000***	-0.000
	(3.28)	(-1.80)
Bargaining Coverage # Year (Linear)		0.003***
		(7.11)
Low Pay # Bargaining Coverage # Year (Linear)		-0.002***
		(-3.87)
High Pay # Bargaining Coverage # Year (Linear)		-0.001***
		(-4.43)
Observations	1,897,524	1,897,524

Note: All models include individual-level controls (age, education, sex) and state-industry-year fixed effects. Low pay refers to low RTI occupations with average income below the country-wide mean, and high pay above the mean. Interaction of bargaining coverage and low/high pay not displayed for brevity. t statistics in parentheses. Standardised coefficients presented for collective bargaining coverage. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.