Embedding skill bias: Technology, institutions, and inequality in wages and benefits

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Abstract

Is rising inequality an inevitable consequence of the transition to a knowledge-based economy? Departing from existing approaches in labour economics and comparative political economy, we develop an account of inequality in the knowledge economy that foregrounds the role of labour market institutions. We argue that collective bargaining institutions play a critical role in mediating the skill bias commonly associated with the diffusion of information and communications technologies (ICT), because they determine whether employers have the discretion to selectively reward strategically important high-skilled workers with greater wages and benefits. We then test our argument by carrying out cross-country analyses of both wage premia and non-wage benefits in the OECD countries. We find robust evidence in support of our theoretical propositions across a range of model specifications.

Keywords: Comparative political economy, knowledge economy, digitalisation, labour market institutions, employer discretion, skill bias, inequality.

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1. Introduction

The question of whether inequality is inherent in the transition to a post-Fordist knowledge-based economy is central to recent debates in both economics and comparative political economy. Labour economists have addressed the question by bringing the relationship between skills and technology to the fore. They have shown convincingly that, as technology permeates labour markets, workers in different types of occupations and holding different types of skills have been affected asymmetrically. Information and communications technology (ICT) in particular has been found to be complementary to highly-skilled workers in non-routine occupations, allowing these workers to command higher wages due to their enhanced productivity. This complementarity (or the lack thereof) has led to the stagnation of wages of workers lower down the skills distribution. Consequently, the asymmetric relationship between technology and skills has been singled out as a major source of income inequality in the transition to a post-Fordist, knowledge-based economy.[1] Inequality, according to this view, is driven by the supply and demand of technology and skills, and it can only be reduced if educational expansion outpaces technology, lowering the wage premium of highly educated workers.[2]

Comparative political economy (CPE) provides a different perspective. While CPE scholars acknowledge the importance of technology in reshaping contemporary labour markets, they have focussed on the policies that influence inequality as well as on the politics that underpin different policy choices. One strand of research in CPE highlights the transformation of actors and institutions – such as trade unions and collective bargaining – that were crucial in ensuring a more egalitarian distribution of income during the Fordist era[3] and points to the difficulty of achieving the same outcome in the post-Fordist era. Other scholars in the CPE tradition suggest that the transition to a knowledge-based economy can be reconciled with egalitarian outcomes, provided that an appropriate set of education and "social

investment" policies is put in place that allows a greater share of the workforce to reap the benefits of changing labour markets.[4]

This paper draws on both the labour economics and CPE lines of research but – in doing so – develops a distinct argument to explain income inequality in the knowledge economy. We start from the assumption put forward by labour economists of a complementarity between high-level skills and technology, which gives university-educated workers a competitive advantage over the rest of the workforce. We theorise that this complementarity allows university-educated workers not only to command sizeable wage premia but also to obtain higher non-wage benefits, both of which are deployed selectively by employers to attract and retain those workers who are considered of strategic importance in the knowledge economy.[5]

However, we argue that institutions – and in particular collective bargaining institutions – play a critical role in mediating the returns that stem from the complementarity between high skills and technology. It is only where collective bargaining is weak that employers are able to apply greater discretion in targeting particular groups of workers and to selectively reward them via wages and benefits. We submit, in short, that the transition to the knowledge economy creates a skill bias in wages and benefits but that the size of that bias is ultimately shaped by collective bargaining institutions. Our argument offers a distinct perspective on income inequality in the knowledge economy vis-à-vis the dominant views in both labour economics and CPE. Conceiving of inequality as embedded in institutions that constrain or amplify employer discretion offers a different take from the labour economics approach, which understands wage inequality as the product of a functional relationship between technology and skills, and from the recent CPE literature, which stresses the role of education and social investment in achieving solidaristic outcomes in the transition to the knowledge economy.

Empirically, the paper focuses not only on wage premia but also conducts one of the first cross-country analyses of non-wage benefits in the form of occupational welfare. We find

strong evidence in favour of our argument. Across a number of different model specifications and including control variables that account for the main alternative explanations of inequality, our analysis shows that technological change drives up wage premia and non-wage benefits for university-educated workers, but that this skill bias is larger for countries in which collective bargaining institutions are weak, whereas it is mitigated almost entirely in countries where those institutions have remained relatively intact. An important if ancillary part of our analysis also suggests that the presence of collective bargaining does not undermine countries' ability to transition into a knowledge-based economy, ruling out the possibility that the mechanism through which collective bargaining keeps inequality at bay is by inhibiting the adoption of technology. To the contrary – and echoing recent findings in the literature[6] – collective bargaining has a positive and significant effect on our measure of technological change. Put differently, collective bargaining institutions do not appear to create a trade-off between equality and the adoption of new technology. Instead, they support both.

2. Inequality, social solidarity and post-Fordism

A major socio-economic correlate of the transition from a Fordist to a post-Fordist, knowledge-based economy is rising inequality across the advanced capitalist democracies.[7] Examining the root causes of this trend, seminal work in labour economics has put skills and technology under the spotlight. The upshot of these analyses is that the diffusion of technology – and in particular of ICT – has profound and asymmetric implications for workers depending on their skill levels. These processes have been theorised by labour economists through the notions of skill-biased technological change (SBTC) and routine-biased technological change (RBTC).[8] SBTC posits that there is a linear relationship between skills and technology, whereby the latter complements jobs with high skill-content (typically jobs that require a college education) and replaces workers lower down the skills distribution. RBTC argues that technology has a U-

shaped effect on the labour market, replacing jobs in the middle of the skills distribution that tend to be associated with "routine" tasks, while complementing those at the high end of the skills distribution and only marginally affecting a set of non-routine occupations at the low end of the skills distribution such as the hospitality sector.[9]

Despite their different predictions concerning the bottom of the skills distribution, both approaches highlight how highly-skilled workers are in an advantageous position as technology permeates the labour market, given the productivity-enhancing effect of ICT on those whose skills are complementary to technology. According to labour economists, the asymmetric effects of ICT can be expected to translate into robust wage premia for college-educated workers until educational expansion "catches up" with the expansion of technology across the labour market, in what has famously been depicted as the "race between education and technology".[10]

While these views capture a powerful motor of rising income inequality in the 21st century, they remain largely silent on one of the major findings of the comparative political economy (CPE) literature, namely, that cross-country variation in distributional outcomes is not only shaped by the supply and demand of production factors, but also by political-institutional variables and governments' policy choices.[11] To be sure, this does not imply that labour economists and other scholars of labour have ignored the role of institutions and policies. However, recent accounts that do reflect on the mediating role of labour market institutions for the distributional consequences of technological change have tended to do so with a single-country focus, typically analysing the United States, which fails to capture important differences across the advanced capitalist democracies.[12]

Recent CPE scholarship on the transition to the knowledge economy concurs with labour economics insofar as the diffusion of ICT drives a wedge between highly-skilled workers and the rest of the workforce,[13] compromising the cross-class solidarity that had

allowed skilled and semi-skilled workers to extract joint gains during the Fordist era.[14] Yet, CPE also enriches this view in two important respects. First, it highlights how the breakdown of social solidarity is not exclusively driven by the functional pressures of technological change but is also rooted in domestic political developments and deliberate policy choices. Second, it highlights the political conditions under which certain policy choices that counter the rise of inequality in the transition to the knowledge economy can be expected to be made.

In particular, we identify three main lines of reasoning that have structured recent CPE debates on the topic. A first group of authors offers a pessimistic view on the possibility of upholding social solidarity in the transition to a post-Fordist economy.[15] These contributions stress the relentless weakening of the actors (such as trade unions) and institutions (such as collective bargaining) that ensured egalitarian outcomes in the Fordist era, including in cases where either or both appear to have remained stable on the surface.[16] A key characteristic of the formal and informal decline of these actors and institutions has been ever greater employer discretion in determining workers' (mis-)fortunes, alongside a broader trend away from authoritative, collective and institutionally-mediated societal arrangements toward fragmented, lower-level and market-driven processes.[17] These accounts – commonly subsumed under the notion of "liberalisation" scholarship – predict capital to be the winner of the transition to post-Fordism and workers to find themselves at the losing end.

While broadly situated in the context of the transition from Fordism to post-Fordism, these analyses do not explicitly take the role of technology into account. More recent contributions have addressed this shortcoming by developing the notion of "skill-biased liberalisation", showing that where political-economic developments unfolded in line with the expectations of liberalisation scholars, highly-skilled workers have in fact also benefitted alongside employers.[18] The mechanism highlighted in this recent extension of the conventional liberalisation thesis is that as market mechanisms gain precedence over coordinating

institutions, those workers whose skills are complementary to technology are able to extract gains (such as higher wages) by virtue of their complementarity with ICT.[19]

At the other end of the spectrum, a second, more optimistic view has been put forward by Torben Iversen and David Soskice.[20] In characterising the relationship between democracy and capitalism as symbiotic, the authors propose a framework of mutually reinforcing relationships between government, business, and the electorate in the knowledge economy. Business in the advanced sectors requires high-level skills, the electorate demands public goods in the form of (higher) education to maximise their chances in knowledge-based labour markets, and governments are keen on providing both – allowing policy-makers to respond to the demands of voters and businesses *simultaneously*.[21] From this vantage point, electoral politics holds the key to sustaining solidaristic outcomes in the knowledge economy, given that large segments of the electorate – chiefly the upper and (aspirational) middle classes – draw material benefits from and demand investments in higher education, which is further expected to gradually expand the pool of winners from knowledge-based growth.

A third diagnosis takes an intermediate position between post-Fordist pessimists and optimists, pointing to the possibility of upholding social solidarity but also identifying rather specific (and limited) political-economic constellations under which this can be expected to happen.[22] These contributions suggest that achieving egalitarian outcomes in the knowledge economy is possible, provided that adequate policies are put in place to equip a large share of the population with the high quality skills needed to thrive in knowledge-based labour markets. In particular, it is suggested that equality in the knowledge economy can be achieved through "embedded flexibilisation"[23] or "inclusive social investment",[24] both of which rest upon a set of specific political-institutional conditions. These include the presence of encompassing organised interest associations,[25] a strong state,[26] broad and stable centre-left coalition between

educated middle class and working class voters[27] or high levels of government satisfaction among voters,[28] which can typically be found in the Nordic countries only.

In developing our theoretical argument, we draw on important insights of the extant CPE approaches reviewed here, but we also suggest that a distinct approach should be pursued to explain patterns of inequality in the transition to the knowledge economy: one that foregrounds institutions in the realm of labour markets and industrial relations.

3. An institutionalist account of inequality in the knowledge economy

This section builds on – but also critically appraises – the above strands in the literature to formulate an alternative argument that can help explain distributional outcomes in the knowledge economy. We argue that the labour economics view on the relationship between education and technology provides strong foundations and that the role of technology has been underappreciated in much of the recent CPE literature insofar as technology appears as a contextual background factor without, however, being systematically investigated empirically. From the CPE literature, on the other hand, we retain the core idea that political-institutional factors play a crucial role in shaping distributional outcomes, but we suggest that the approaches reviewed above face two theoretical issues.

First, despite proposing different political mechanisms, Iversen and Soskice,[29] Garritzmann, Häusermann, and Palier,[30] and Thelen[31] ultimately point to the predominant role of *policies* in shaping distributional outcomes, and to robust education and other social investment policies in particular. These approaches are by no means blind to institutions. But institutions feature most prominently as *enabling* the emergence of certain redistributive policies and therefore act *through* policies.[32] However, the extent to which education and social investment policies can uphold egalitarian outcomes is far from clear. The continuous expansion of higher education, for example, might not be matched by a congruent expansion

of knowledge-based and well-remunerated jobs. After all, instances of skills mismatch[33] and of college graduates "queuing" for a limited pool of "good jobs"[34] are well-documented in the literature. Recent research on the British case in particular provides strong evidence against the proposition that egalitarian outcomes in the knowledge economy are achieved via skill-oriented approaches like the expansion of higher education.[35] Relying on the broader social investment package is no panacea either in this regard. Consider the example of active labour market policies (ALMPs). If we accept the insight from labour economics of a complementarity between college education and ICT, then the extent to which even a high-quality system of ALMPs can generate equal distributional outcomes is doubtful, since the skills formed through ALMP training are not usually the type of higher (cognitive) skills that are enhanced by technology and are rewarded in the context of its growing use.

Second, we contend that the liberalisation thesis tends to conflate the decline in the institutions that ensured egalitarian outcomes in the Fordist era (e.g., collective bargaining) with the decline of the actors that created and sustained them (e.g., trade unions and social-democratic parties). While it is clear that the latter underwent a secular decline in the majority of advanced capitalist democracies, as indicated by falling union density[36] and a decreasing share of votes for centre-left parties,[37] formal corporatist institutions have displayed far greater resilience. Jahn's prescient study of corporatist arrangements across 42 countries over five decades is a case in point, as it illustrates how corporatism has not decreased universally.[38] Instead, the analysis reveals cases of deterioration alongside cases of stability and even cases of expansion. Recent works by Hope and Martelli,[39] Huber, Huo and Stephens,[40] and Kristal and Edler[41] show how such variation in national labour market institutions can explain variation in (top) income inequality in the transition to the knowledge economy, suggesting that labour market institutions continue to be "important safeguards of wage solidarity".[42] This calls into question a key proposition of liberalisation scholarship, namely, that *formal* stability

in institutional arrangements in the realm of labour markets and industrial relations conceals the fact that these institutions have been reconfigured *informally* to such an extent that their effectiveness in maintaining egalitarian outcomes has been undermined. We shall treat this is an open empirical question in our analysis: if formal institutions have indeed been informally reconfigured and emptied of their ability to shape distributional outcomes, we should expect variation in formal institutions to have no effect on (in-)equality in the knowledge economy. If, on the other hand, formal institutions "still matter", we should expect distributional outcomes to vary with their strength. The empirical analysis we present in Section 4 lends support to the latter.

In paving the way for our argument, this section has sought to highlight two main points. First, there are plausible theoretical reservations about the effectiveness of skill-oriented policies alone in curbing inequalities in the post-Fordist knowledge-based economy. Second, labour market institutions are "stickier" than the (weakening) actors that have historically supported them and continue to vary significantly across countries. Taken together, these insights assign a central role to labour market institutions alongside technological change and skills in understanding the distributional implications of the knowledge economy, challenging recent CPE literature on the topic that has focussed on the role of education and skills policies.[43]

We now turn to our theoretical argument which we develop in two steps. Firstly, we build on Iversen and Soskice's conceptualisation of the relationship between skills and technology,[44] which offers a more nuanced perspective compared to the standard labour economics view. The authors argue that high-level skills and ICT are indeed complementary but qualify this proposition in important ways. In particular, they suggest that the "returns" that high-skilled workers generate for firms through their complementarity with technology depend on both their individual skills and their interaction with other high-skilled workers. As such, they expect that returns on technology are maximized when highly-skilled workers develop

relations "over historical time", that is, via sustained physical co-location for extended periods within companies or knowledge clusters.[45] Put simply, a company in an advanced sector like high-tech manufacturing is expected to maximise the returns on ICT *if* a certain group of highly-skilled workers, such as engineers, stay in the company *and* work together for a prolonged period of time.

We see two important implications in Iversen and Soskice's notion of "historical relations". First, it qualifies the "race between education and technology" approach by pointing to the potential for highly-skilled workers to command significant wage premia even as their supply increases, because – when accounting for historical relationships – not every equally highly qualified worker is worth the same for a firm. Second, if firms are to foster historical relationships, they will need to not only recruit but also *retain* highly-skilled workers. To this end, recent research has shown that firms not only use (high) wages to attract highly-skilled workers but also non-wage benefits, such as company-sponsored welfare, to tie otherwise potentially highly mobile knowledge workers to firms for extended periods of time.[46] This leads us to conjecture that (i) given the complementarity between highly-skilled workers and ICT and (ii) given the need to both recruit and retain highly-skilled workers, the transition to the knowledge economy can be expected to be characterised by inequalities not only in wages but also in non-wage benefits, and that skill level will be a key dimension structuring both forms of inequality. Thus, as the use of ICT increases, we would expect employers to try and concentrate wages and non-wage benefits on highly-skilled workers in order to maximise the returns on technology.

But what determines whether employers can pursue a strategy of selectively rewarding highly-skilled workers? We argue, secondly, that the extent to which workers can be selectively rewarded is a function of national labour market institutions. The notion of *selectively* recompensing a specific group of workers speaks directly to the liberalisation literature which

considers "employer discretion" to be the key observable implication of the erosion of collectivist institutions.[47] One mechanism that enables employers in more liberalised political economies to selectively attract and retain what they deem to be strategically important workers has been highlighted by Martin and Swank[48] and Thelen[49]: as institutions of collective bargaining break down, firms can cut costs lower down the skills distribution and redeploy resources towards highly-skilled workers. By contrast, to the extent that collective bargaining is still intact, it provides an institutionalised mechanism for workers lower down the skills distribution to align their wages and non-wage benefits with those of highly-skilled workers across the political economy.[50]

In other words, given that collective bargaining institutions and (formal) employer discretion are inversely related, we expect the ability of highly-skilled workers to extract higher wages and benefits and/or the ability of employers to reward such workers with higher wages and benefits to increase in liberalised political economies where employer discretion is greater. Conversely, the more processes to set wages and non-wage benefits are shaped by authoritative coordinating mechanisms like collective bargaining, the less employers can be expected to be able to selectively reward highly-skilled workers and/or the less these workers will be able to extract wage premia and benefits exclusively for themselves by virtue of their "individual" market power. There are good reasons to expect the same logic – of gains accruing at the top of the skills distribution the more labour market institutions are liberalized – to apply to *both* wages *and* benefits. As Kristal, Cohen, and Nadot have shown for the case of the US, inequality in benefits has, if anything, been even more pronounced than inequality in wages.[51] The authors suggest that this is largely due to benefits being determined at the firm-level, in combination with a decline in union coverage rates and the liberalisation of employment practices, such as the rise of low-wage part-time work contracts and the proliferation of performance-pay packages. Conversely, the authors claim that both wage inequality and "benefit inequality is

likely lower in countries with (…) stronger labor market regulations"[52] – a claim which we put to the test in a novel cross-country empirical analysis in Section 4.2 below.

In sum, our theoretical contention is two-fold. First, technological change strengthens the labour market position of university graduates and pushes firms to create the conditions for building historical relationships among highly-skilled workers. This is achieved by selectively deploying higher wages and non-wage benefits to this group of workers. Second, the labour market advantage of university-educated workers is mediated by the institutional context, since the (in-)ability of employers to reward highly-skilled workers discretionarily and selectively goes hand-in-hand with the (lack of) liberalisation of formal collective bargaining institutions at the national level. We submit, therefore, that the skill-bias in wages and non-wage benefits in the transition to the knowledge economy is not only a function of the relationship between skills and technology. Rather, it is *institutionally embedded*.

4. Empirical analysis

The empirical analysis in the paper is broken down into two parts. The first analysis utilises national-level panel data and focuses on wage premia (Section 4.1). The second analysis uses multi-level modelling and focuses on non-wage benefits (Section 4.2).

4.1. Wage premia analysis

4.1.1. Data

Our national-level dataset for the wage premia analysis covers 15 Organisation for Economic Co-operation and Development (OECD) countries and runs from 1995 – 2017. The time period we analyse is largely dictated by data availability, but matches up nicely with the era of knowledge-based growth in the capitalist democracies.[53] For a complete list of variables and sources for the wage premia analysis, see Table A1 in the Appendix.

The dependent variable in the analysis is the wage premia for university-educated workers. The best available measure of this variable that is comparable across countries and over time, and hence suitable for panel data analysis, is Weisstanner and Armingeon's measure of the education premium,[54] which looks at earnings differentials between workers with and without tertiary education. As this measure is only available for selected years and countries, however, it does not provide sufficient statistical power to test our central theoretical propositions (its use reduces the overall sample size for our analysis to just 70-80 observations; see Table A6 in the Appendix). Given that, we use a proxy for the wage premia that has considerably better coverage: the 90-50 gross earnings ratio. This measure allows for an overall sample size for our analysis of 200-225 observations (see Table A3 in the Appendix). This measures the ratio of the gross earnings of the worker at the 90th percentile of the earnings distribution to the gross earnings of the worker at the 50th percentile of the earnings distribution. It is often referred to as a measure of 'upper-tail inequality'.[55] The data for this measure are taken from the Comparative Welfare States Data Set.[56] The underlying data are from the OECD Labour Force Statistics.[57]

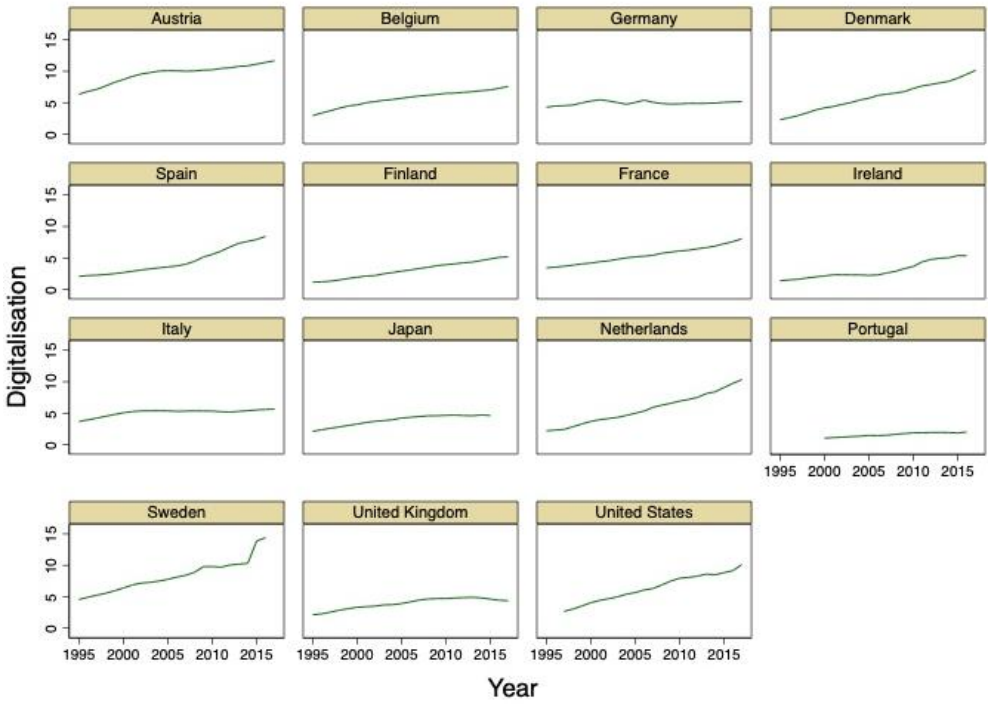
A large body of empirical work in labour economics has shown that the rising education premium has been the driving force behind increases in upper tail inequality in the advanced democracies since the 1980s.[58] The 90-50 gross earnings ratio is also highly correlated (0.88) with Weisstanner and Armingeon's measure for the limited number of years in which the data overlap. This strong correlation is further highlighted in Figure A1 in the Appendix, which plots the measures against one another.

The first key independent variable in the analysis is technological change. We measure this by calculating the level of digitalisation across countries using data from the 2019 release of the EU Level Analysis of Capital, Labour, Energy, Materials and Service Inputs Database (EU-KLEMS).[59] Digitalisation is calculated as the ICT capital stock per employee in €1,000,

where the ICT capital stock is the sum of fixed capital stocks in computing equipment, communications equipment, and computer software and databases.[60] The data are in constant 2010 €s. For non-euro countries, the data have been converted to euros using 2010 exchange rates. This measure of technological change focuses specifically on ICT, which aligns closely with our theoretical argument about the complementarity between ICT and high skills. Another advantage of using this independent variable is that the EU-KLEMS data are harmonised to ensure comparability across countries and over time, making it well-suited for panel analysis.

Figure 1 shows the variable for the 15 countries in our sample between 1995 and 2017. It is clear digitalisation has been ubiquitous in the advanced capitalist democracies over this period, although the pace of digitalisation has been far from uniform across countries.

Figure 1. Digitalisation in 15 advanced democracies, 1995 - 2017



Note: Digitalisation is the ICT capital stock per employee in €1,000 (constant 2010 prices).

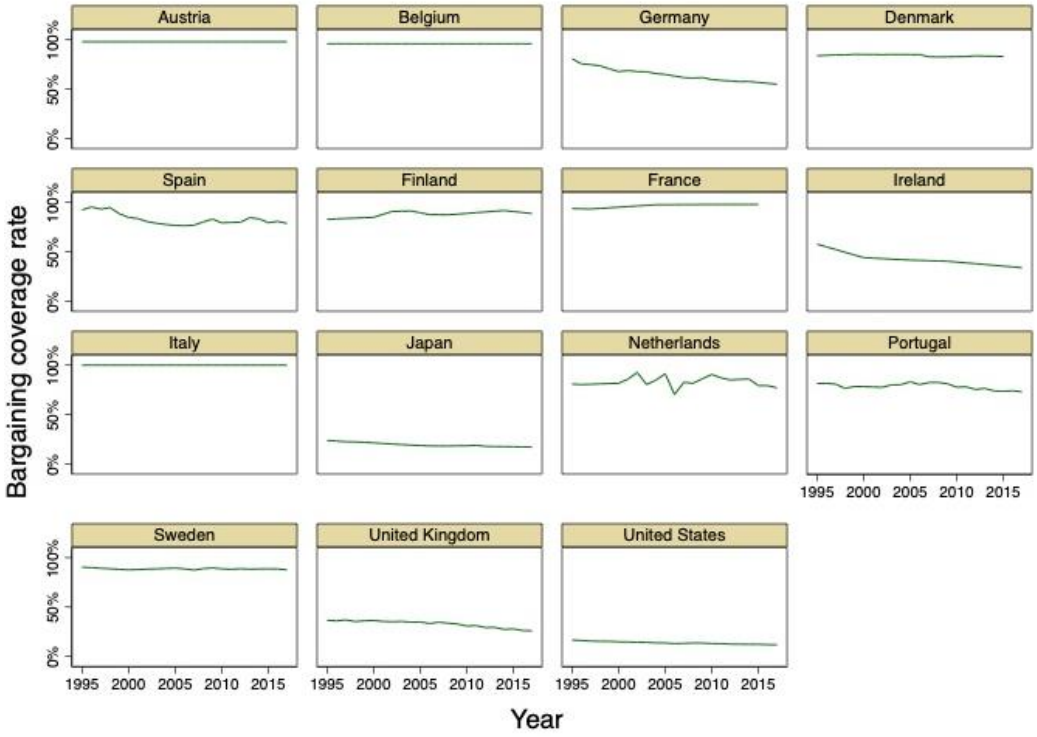
Source: Authors' calculations using the 2019 release of the EU-KLEMS.

The other central feature of our theoretical framework is employers' discretion in setting wages and non-wage benefits. In line with our proposition that collective bargaining institutions and employers' discretion are inversely related, we proxy discretion by using the national-level bargaining coverage rate, which is the proportion of employees covered by collective agreements in force among employees with the right to bargain. We follow Sochas and Reeves in selecting bargaining coverage over other related institutional measures (such as degree of centralisation or type of collective bargaining) for both theoretical and empirical reasons.[61] Theoretically, the higher bargaining coverage rates, the less we would expect employers to be able to selectively reward high-skilled workers, because under high rates of bargaining coverage a larger share of lower skilled workers have an institutional mechanism through which to link their wages and non-wage benefits to those of high-skilled workers. Empirically, bargaining coverage offers "a unidimensional, continuous measure that is associated with a set of other important institutional dimensions [that] are not independent of one another" and that collective bargaining can conveniently proxy.[62] Bargaining coverage, in short, provides us with reliable information on the share of workers whose wages and benefits are collectively bargained, which is a theoretically and empirically effective way to capture "how much" discretion employers have in setting wages and benefits. This measure is taken from the OECD Institutional Characteristics of Trade Unions, Wage Setting, State Intervention and Social Pacts Database (OECD/AIAS ICTWSS 2021) and is based on combined administrative and/or survey data sources. As this variable is slow-moving, we linearly interpolate missing values.[63]

Figure 2 shows how bargaining coverage rates have evolved between 1995 and 2017 in the 15 countries in our sample. We can see substantial variation across countries in both levels and trends. The Anglo-Saxon countries started the period with much lower bargaining coverage and saw even further liberalisation over time. At the other end of the scale, several Nordic and continental European countries started the period with high bargaining coverage

and saw little change over time. Lastly, there are some countries, such as Germany and Spain, that saw their high bargaining coverage gradually eroded over this period.

Figure 2. Bargaining coverage rates in 15 advanced democracies, 1995 - 2017



Note: The bargaining coverage rate is the proportion of employees covered by collective (wage) agreements in force among employees with the right to bargain.

Source: OECD/AIAS ICTWSS Database 2021.

Crucially for our empirical analysis, there does not appear to be a strong link between technological change and employer discretion. Our measures of digitalisation and the bargaining coverage rate are not highly correlated with one another (0.22).[64] Taking a pertinent two country example, the US has the lowest bargaining coverage rate in the sample and Austria has one of the highest, yet both countries have seen rapid digitalisation since the mid-1990s. It is also evident from Figures 1 and 2 more broadly that high collective bargaining rates have not precluded countries from successfully transitioning to the knowledge economy. In Section 4.1.4, after we have presented our main results, we will explore the relationship between

digitalisation and bargaining coverage rates in a more rigorous panel data analysis in order to rule out one of the main alternative explanations for our findings.

We also gather data for a number of control variables. Most importantly, we collect OECD data on the share of 25-64 year olds that are tertiary educated.[65] This helps control for the supply of university graduates, which has been shown to strongly affect the college wage premia in Goldin and Katz's influential work on the race between technology and education.[66] We also include controls to account for factors that the existing CPE literature has highlighted as important for affecting distributive outcomes in the knowledge economy; namely public expenditure on ALMPs (as a % of GDP), gross domestic spending on research and development (R&D) (as a % of GDP), and trade union density (all from the OECD). These three variables aim to control for, respectively, social investment policies,[67] spending on innovation in advanced sectors,[68] and the changing strength of the actors that traditionally supported collective bargaining institutions.[69]

The remaining controls in our national-level dataset are a range of economic and political variables that are typically used in empirical studies of wage inequality.[70] Specifically, we take data from the OECD on the unemployment rate, trade openness (as a % of GDP), private debt (as a % of GDP) and GDP per capita (constant prices and exchange rates),[71] as well as data from the Comparative Welfare States Data Set on the cumulative share of left parties in the government.[72,73]

4.1.2. Empirical strategy

Our exploration of the wage premia for high-skilled workers in advanced democracies utilises panel data regression analysis. Our central modelling approach incorporates country and time fixed effects and robust standard errors. This approach controls for time-invariant, unobserved heterogeneity at the unit level, as well as for common shocks affecting wage premia in the

advanced capitalist democracies across the period. We use a stepwise approach to ensure that our results are not driven by our choice of covariates. We first estimate a model including only our main independent variables of interest: digitalisation and the bargaining coverage rate. We then we add in our full set of control variables. Crucially for testing our central theoretical proposition, both models also include an interaction effect between our two main independent variables. The regression equations estimated in the wage premia analysis are set out in full in the Appendix.

We also check the robustness of our results to a number of alternative specifications. First, we estimate models with a linear time trend instead of time fixed effects, as well as estimating random effects and Prais-Winsten regression models. To assuage concerns about simultaneity bias driving our main results, we also estimate a model with all the independent variables lagged by one period. The results of these alternative specifications are shown in Table A4 of the Appendix. We also check the robustness of the results to not using the linearly interpolated data points for the bargaining coverage rate and to using an alternative education variable that measures overall spending on education (as a % of GNI) (Table A5 in the Appendix). We also re-run our main models using Weisstanner and Armingeon's measure of the education premium as an alternative dependent variable (Table A6 in the Appendix).[74] Furthermore, we check the robustness of our results to including additional control variables for the centralisation of collective bargaining and the type of coordination of wage setting, which Traxler and Brandl show can, under certain circumstances, also affect the distribution of earnings alongside the bargaining coverage rate (Table A7 in the Appendix).[75] Lastly, we run a placebo test replacing the 90-50 gross earnings ratio with the 50-10 gross earnings ratio as the dependent variable in our regression models (Table A8 in the Appendix). Given that our theoretical proposition is specifically centred on the labour market advantage that technological change bestows on university-educated workers, we would not expect to see similar effects

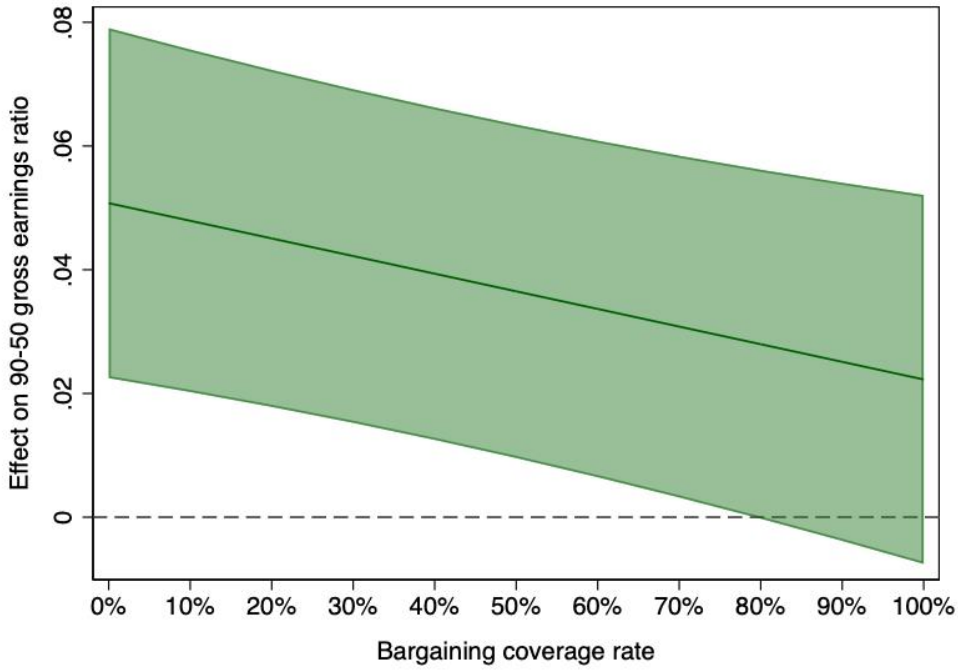
when looking at inequality in the bottom half of the income distribution (where the majority of workers do not possess a university education). Hence, statistically insignificant results in our placebo test would provide further evidence in support of our theorisation.

4.1.3. Results

Figure 3 presents the central results of our wage premia analysis. It shows how the average marginal effects of digitalisation on the 90-50 gross earnings ratio differ depending on the bargaining coverage rate (for the model with all controls). We can see that digitalisation is associated with increases in the wage premia and that this effect is largest at low rates of bargaining coverage. When bargaining coverage rates exceed around 80%, the effects of digitalisation on the wage premia become statistically insignificant (although the point estimates are still positive). In line with our theoretical expectations, our results therefore show that the effect of digitalisation on the high-skill wage premia is greater when the bargaining coverage rate is lower (or, conversely, when employers have more discretion to set wages and differentiate among workers based on skill levels). The full regression results are shown in Table A3 in the Appendix.

In countries where employers have a lot of discretion to set wages, the magnitude of the effects is also substantial. For instance, when the bargaining coverage rate is at 12% (the level in the US in 2016), an increase in digitalisation by one standard deviation (2.49) is associated with an increase in the wage premia of 0.12. To put this figure into perspective, this is equivalent to the rise in the 90-50 gross earnings ratio the US experienced during the period of growing inequality from 2004 to 2016.

Figure 3. Average marginal effects of digitalisation on 90-50 gross earnings ratio (model with all controls; 95% CIs)



Given that panel data analyses can be particularly sensitive to modelling choices,[76] we ran several robustness checks, which are presented in Tables A4-A8 in the Appendix. Across a range of alternative specifications (Table A4), we see our main results hold; digitalisation is positively and statistically significantly associated with the wage premia, and the interaction effect of digitalisation and the bargaining coverage rate is negative and statistically significant.

Our main results are also robust to dropping the linearly interpolated values for the bargaining coverage rate and to using an alternative education variable that measures overall education expenditure (Table A5). We also show the main relationships are replicated when using Weisstanner and Armingeon's measure of education premia as an alternative dependent variable (Table A6).[77] Given this alternative dependent variable has considerably poorer country-year coverage than our main dependent variable, the sample size for this analysis falls to just 70-80 observations. This reduces the statistical power of the analysis to such an extent

that the results are not statistically significant, but the direction and magnitude of the main coefficients is in line with our main results.

Furthermore, our main results are robust to including additional controls variables to account for the degree of centralisation of collective bargaining and the type of coordination of wage setting (Table A7). Lastly, Table A8 presents the results of our placebo test with the 50-10 gross earnings ratio (a measure of inequality in the bottom half of the income distribution) as the dependent variable. We can see that the coefficients on the digitalisation variable and the interaction effect are statistically insignificant in the baseline model and the model with the full set of controls. This further supports our theorisation, which centres around the increasing importance of university-educated workers to firms in the knowledge economy, as it shows that the skill bias and the mediating effects of collective bargaining institutions are confined to the top half of the income distribution.

4.1.4. Assessing the main alternative explanation

An alternative explanation for the findings of our wage premia analysis is that high bargaining coverage rates supress earnings inequalities by limiting technological progress. To allay any fears that this is the main mechanism driving our results, we run a panel data analysis with digitalisation as the dependent variable and the bargaining coverage rate as our main independent variable. We include a number of national-level control variables (taken from the dataset for the main wage premia analysis). We also include a measure of GDP (constant prices, constant purchasing power parities) from the OECD National Accounts to take into account the size of countries, as smaller countries may be able to digitalise more rapidly. As in our main analysis, we use two-way fixed effect models and take a stepwise approach, running a model without controls and then adding our full set of controls.

We find in both models (full regression results in Table A9 in the Appendix) that the bargaining coverage rate is positively associated with digitalisation, which provides strong evidence against this alternative explanation for our findings. Taken together, the wage premia and digitalisation analyses in this section suggest that collective bargaining institutions are able to support solidaristic outcomes in the labour market and aid the transition to the knowledge economy simultaneously. Our results also align with recent contributions in CPE that emphasise the positive role that collectivist institutions can play in driving technological adoption,[78] through imposing a "beneficial constraint" on firms.[79]

4.2. Non-wage benefits analysis

4.2.1. Data

We are required to change tact in our non-wage benefits analysis, as there is no national-level dataset (that we are aware of) on non-wage benefits and their distribution across the skill distribution. We therefore turn to individual-level survey data from the European Working Conditions Survey (EWCS). This survey is conducted on a random sample of employees and the self-employed in over 30 European countries. For consistency with our wage premia analysis and our theoretical focus, we restrict the sample to the countries that appear in the first part of our empirical analysis. We thus have to drop four countries from the analysis because they are either not in the EWCS (Japan and the US) or do not have data available for the (industry-level) digitalisation variable used in the non-wage analysis (Ireland and Portugal).[80] Our individual-level data for the non-wage benefits analysis therefore covers 11 OECD countries in 2005, 2010 and 2015 (the three most recent waves of the EWCS). The total sample size for the analysis is 38,541 observations for the model without controls and 29,999 observations for model with controls (see Table A10 in the Appendix). For a complete list of variables and sources for the non-wage benefits analysis, see Table A2 in the Appendix.

The binary dependent variable in our non-wage benefits analysis is the following question (0 = No; 1 = Yes) from the EWCS: 'With regard to your earnings from your main job, do they include advantages of any other nature (for instance, medical services, access to shops, etc.)?'. This is the most suitable question in the survey to ascertain whether employees are receiving non-wage benefits and is also utilised in Riva and Rizza,[81] the only other cross-national empirical study (we are aware of) that looks at the determinants of access to non-wage benefits. Importantly, this measure should pick up access to employer-provided social benefits, such as health insurance, as well as the broader range of non-pecuniary benefits that employers may provide to their employees, such as access to shops, company cars, or subsidised food.

The main independent variables are digitalisation at the industry level (calculated from the EU-KLEMS dataset using the method outlined in Section 4.1.1) and a binary variable for whether individuals have tertiary education (taken from the EWCS). The latter is '1' if an individual's highest level of education or training is the first or second stage of tertiary education according to the International Standard Classification of Education (i.e., ISCED 1997 levels 5 or 6) and '0' otherwise. Aligning with the wage premia analysis, the extent of employer discretion is measured by national-level bargaining coverage rates taken from the OECD/AIAS ICTWSS Database 2021.

We also add a set of individual-level controls variables from the EWCS similar to those used in Riva and Rizza.[82] Specifically, gender (0=male; 1=female), age (3 categories), contract type (5 categories), and number of employees working in the establishment (5 categories). Access to non-wage benefits has been shown to vary substantially across these individual-level characteristics in the advanced capitalist democracies,[83] so it is important to account for them in our analysis.

4.2.2. Empirical strategy

Our non-wage analysis has a binary dependent variable, so we use linear probability models as our central approach. We choose linear probability models over probit or logit models, as they are more efficient and easier to interpret. In alignment with our wage premia analysis and to account for the multi-level structure of our data, we also include country and year (i.e., wave) fixed effects and robust standards errors. The main independent variables in the analysis are digitalisation at the industry level and a dummy variable for whether an individual has completed tertiary education. We first estimate a baseline model with no controls, and then we add in our set of individual-level control variables. To allow us to test whether there is a skill bias for non-wage benefits, both models also contain an interaction effect between the two main independent variables. The regression equations estimated in the non-wage benefits analysis are set out in full in the Appendix.

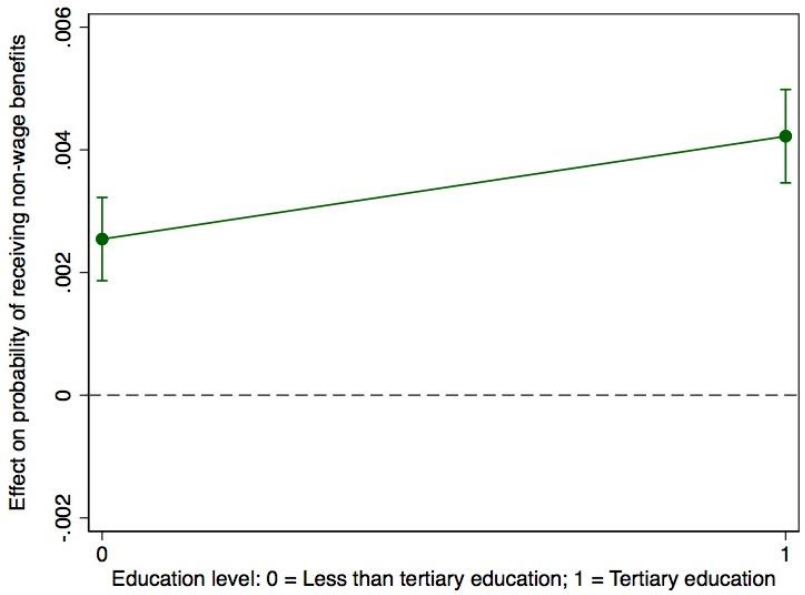
To avoid using a three-way interaction term, we carry out a simple mean split of our sample by average bargaining coverage rates to explore whether the skill bias in non-wage benefits differs in countries with low bargaining coverage (i.e., high employer discretion) and countries with high bargaining coverage (i.e., low employer discretion).

We test the robustness of our non-wage benefits analysis to alternative specifications by re-running the analysis using logistic regression models rather than linear probability models. The results are shown in Tables A12 and A13 in the Appendix. We also check the robustness of the results to including a set of national-level control variables alongside the individual-level control variables. Tables A14 and A15 in the Appendix show the results when the same set of national-level control variables from the wage premia analysis are added into the main models for the non-wage benefits analysis.

4.2.3. Results

Figure 4 presents the results from our non-wage benefit analysis. It shows how the average marginal effect of digitalisation on the probability of receiving non-wage benefits differs for non-tertiary educated and tertiary-educated workers. We can see that digitalisation boosts the probability of receiving non-wage benefits for both sets of workers, but that the effect is substantially larger for workers with a university education. In other words, employers appear to be disproportionately rewarding high-skilled workers with non-wage benefits in digitalising industries. This means, in line with our theoretical expectations, that there is a clear skill bias: digitalisation increases the probability of receiving non-wage benefits more for university-educated workers than it does for non-university-educated workers. The full regression results are shown in Table A10 in the Appendix.

Figure 4. Average marginal effects of digitalisation on probability of receiving non-wage benefits (model with controls; 95% CIs)

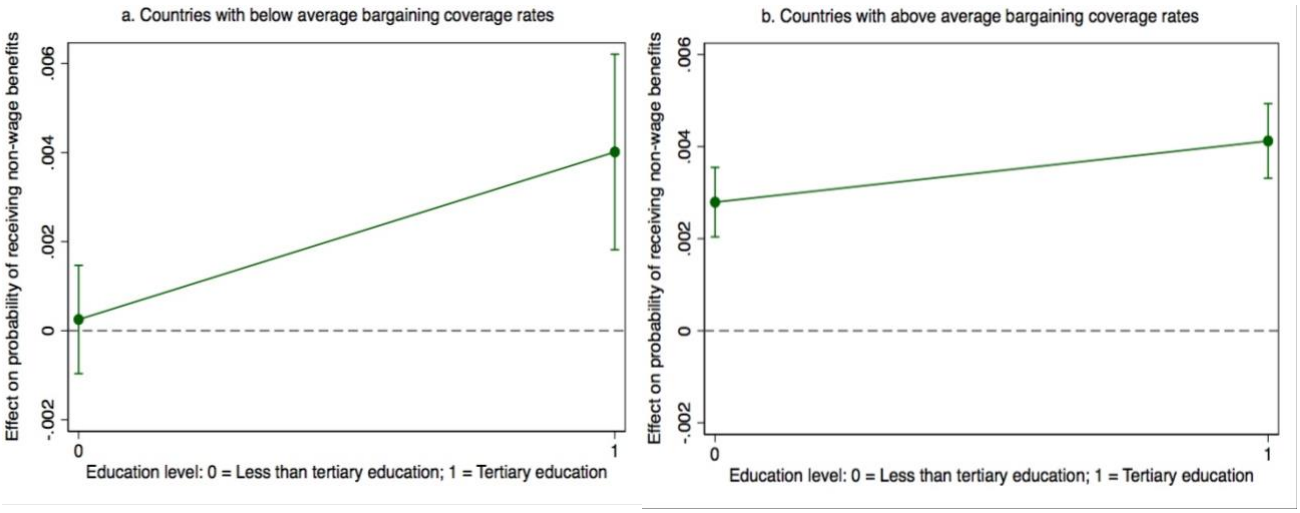


Next, we explore whether the skill bias differs across countries with different levels of employer discretion. To do this, we use a mean split to divide the sample into countries with below and above average bargaining coverage rates. Across the 11 countries in our sample for the three years the EWCS was administered (2005, 2010, and 2015), the average bargaining coverage rate was 82.9%. The countries with an average bargaining coverage rate below this threshold are Germany, Spain and the UK. The countries with an average bargaining coverage rate above this threshold are Austria, Belgium, Denmark, Finland, France, Italy, the Netherlands, and Sweden.

Figure 5 presents the results. It shows the average marginal effects of digitalisation on the probability of receiving non-wage benefits for non-tertiary educated and tertiary educated workers for both sets of countries. We can see that the skill bias is much larger for countries where bargaining coverage is low (i.e., where employers have more discretion). Strikingly, the left panel of Figure 5 shows that digitalisation does not increase the probability of receiving non-wage benefits for non-tertiary educated workers in countries with below average bargaining coverage.

In contrast, the right-hand panel of Figure 5 shows that non-tertiary educated workers see their probability of receiving non-wage benefits increase as their industry digitalises in countries where employers have less discretion in setting wages and non-wage benefits. We interpret this in line with our theoretical argument as being due to collective bargaining providing an institutional mechanism for non-tertiary educated workers to extract similar non-wage benefits from employers to their tertiary educated counterparts.

Figure 5. Average marginal effects of digitalisation on probability of receiving non-wage benefits (model with controls; 95% CIs) – Sample split by bargaining coverage rates



The full regression results for the split sample analysis are shown in Table A11 in the Appendix. In order to test the sensitivity of our results to the modelling approach taken, we re-run our analysis using logistical regression models instead of linear probability models. Tables A12 and A13 in the Appendix show the main results of the non-wage benefits analysis are closely replicated when using this alternative approach. Lastly, Tables A14 and A15 in the Appendix show that the main results hold when we add the same set of national-level control variables from the wage premia analysis.

5. Conclusion

The transition from Fordism to a knowledge-based economy has attracted a lot of attention from both scholars and policy-makers in recent decades – first, because it carried the promise of improved labour market prospects across different strata of society,[84] and later, because it has become evident that this promise has in many cases not been fulfilled.[85] One manifestation of such broken promises has been the growth of income inequality across the advanced capitalist democracies.

Labour economists have pinned the blame for inequality on the widespread diffusion of ICT and the failure of educational attainment to keep pace.[86] Comparative political economists have developed this further by highlighting the importance of inclusive higher education and social investment policies in safeguarding workforce equality in the knowledge economy, while highlighting the relative rarity of durable, cross-class coalitions emerging in support of these policies.[87] The argument we put forward in this paper challenges and qualifies both of these interpretations, suggesting that inequality in the knowledge economy cannot be fully understood without foregrounding the role of labour market institutions, and collective bargaining in particular.

Our analysis provides robust empirical evidence showing that in countries where collective bargaining coverage has remained high, and by implication, where employer discretion to selectively reward high-skilled workers has remained relatively low, technological change is a much less powerful driver of inequality. This supports our central theoretical proposition that the skill biases in wages and benefits commonly associated with technological change are embedded in – and mediated by – labour market institutions. Our analysis holds for both wage premia and non-wage benefits and is robust to a range of alternative specifications. Moreover, we find that the presence of strong collective bargaining institutions does not hinder the adoption of information and communications technology. To the contrary, collectivist institutions seem to reinforce ICT adoption, in line with recent contributions to the CPE literature.[88] This helps rule out the main alternative explanation for our results, namely, that collective bargaining reduces skill biases by hampering the transition to a knowledge-based economy in the first place.

These findings yield two key implications for our understanding of the distributional consequences of the knowledge economy and for comparative scholarship more broadly. First, while our analysis does not reject the notion that expanding (higher) education and other social

investment policies is vital for increasing individual returns from technological change, it cautions against placing too much emphasis on skill-oriented policies alone when it comes to explaining (and mitigating) inequalities in the transition to the knowledge economy. Put differently, the pursuit of social investment policies would appear more justified on efficiency than on equity grounds. To fulfil the promise of the latter, scholars and policy-makers would be well-advised to focus their attention on (strengthening and sustaining) collective bargaining institutions instead. Second, and related, our analysis implies that labour market institutions can have an equalizing effect on wages and non-wage benefits even in the face of a weakening of the actors who traditionally supported them. A pertinent question for future research, then, is whether and how (long) these institutions can be effectively maintained if neither labour[89] nor capital[90] are able or willing to sustain them. Comparative research that transcends the macro-institutional lens of CPE and that draws attention to the organizational and workplace implications of technological change is a suitable candidate for this endeavour.[91]

Notes

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Chris Howell, *Trajectories of Neoliberal Transformation: European Industrial Relations Since the 1970s* (Cambridge University Press, 2017); Wolfgang Streeck, *Re-Forming Capitalism: Institutional Change in the German Political Economy* (Oxford University Press, 2009).

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[20] 2019.

[21] Ibid., 259.

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[25] Cathie Jo Martin and Duane Swank, *The Political Construction of Business Interests: Coordination, Growth, and Equality* (Cambridge University Press, 2012); Thelen, 2014.

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[31] Thelen, 2014.

[32] In Iversen and Soskice's framework, *electoral* institutions shape the extent to which governments compensate through redistributive policies those that are most exposed to social risks in the transition to the knowledge economy. The authors identify in ALMPs a major source of variation between countries that redistribute the most

(i.e. those with proportional systems and weak Christian-Democratic parties), those that redistribute relatively less (proportional systems with strong Christian-Democratic parties), and those that redistribute the least (majoritarian countries). See Iversen, Soskice, 2015; Iversen, Soskice, 2019.

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[39] Hope, Martelli.

[40] Huber, Huo, Stephens.

[41] Kristal, Edler.

[42] Hope, Martelli, 236. While our analysis draws inspiration from and speaks to these extant works, we seek to provide a different theoretical account of the mechanism through which labour market institutions affect inequality, as outlined in the remainder of this section. We also provide novel evidence that collective

bargaining is positively associated with digitalisation. Lastly, we extend the analysis to include inequality in non-wage benefits, which is an important implication of our theoretical argument.

[43] It should be noted that the distinction between policies and institutions can be difficult to establish both conceptually and empirically, especially in the realm of labour markets (as is the case for clauses that automatically extend bargaining coverage, for example). Thus, when juxtaposing labour market institutions with skill-oriented policies, we do not seek to juxtapose institutions and policies *per se*, given the inherent difficulties in disentangling the two, but rather to distinguish the logic of effecting change via the skills lever (e.g., education policy or ALMPs) from that of relying on more explicitly distributive levers (such as collective bargaining).

[44] Iversen, Soskice, 2019.

[45] Ibid., 184–185.

[46] Diessner, Durazzi, Hope; Timo Fleckenstein and Martin Seeleib-Kaiser, "Cross-national perspectives on firm-level family policies: Britain, Germany, and the US compared," in Jochen Clasen, ed., *Converging Worlds of Welfare?: British and German Social Policy in the 21st Century* (Oxford University Press, 2011), 129–154; Tobias Wiß, "From welfare states to welfare sectors: Explaining sectoral differences in occupational pensions with economic and political power of employees," *Journal of European Social Policy*, 25 (2015), 489–504.

[47] Baccaro, Howell, 2017.

[48] Martin, Swank.

[49] Thelen, 2014.

[50] It is worth noting here that our argument differs from the dualization perspective in CPE in two (interrelated) respects. On one hand, our argument implies that the presence of coordinating institutions such as collective bargaining – which dualization scholars posit to be benefitting labour market insiders primarily – can favour low-skilled marginal workers as well, by aligning their wages and non-wage benefits with those of the highly-skilled. On the other hand, core workers – who in the knowledge economy are those with high skills complementary to technology – can gain an advantageous position on the labour market in the *absence* of coordinating institutions, as they are able to extract higher wages and non-wage benefits by virtue of their skill level. We are grateful to Patrick Emmenegger for this reflection, without implicating him in its formulation. See also Diessner, Durazzi, Hope; Anke Hassel, "The Paradox of Liberalization — Understanding Dualism and the Recovery of the German Political Economy," *British Journal of Industrial Relations* 52 (March 2014), 57–81

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[61] Laura Sochas and Aaron Reeves, "Does collective bargaining reduce health inequalities between labour market insiders and outsiders?," *Socio-Economic Review*, 21 (April 2023), 827–862.

[62] Ibid., 832–33.

[63] The main results are unaffected if we re-run the analysis without the linearly interpolated values of the bargaining coverage rate. See Table A5 in the Appendix.

[64] The lack of correlation between these measures is further highlighted in the scatterplot in Figure A2 in the Appendix.

[65] Data accessed 25th of May 2022.

[66] Goldin, Katz, 2008.

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Appendix

Table A1. Variables and data sources for national-level wage premia analysis

Variable	Source
Wage premia: 90-50 gross earnings ratio	Comparative Welfare States Data Set (Brady, Huber, and Stephens 2020), compiled from OECD Labour Market Statistics (data accessed 22 Jan 2019)
Education premium: Percentage difference of median pre-tax earnings of full-time workers with tertiary education relative to workers without tertiary education	Weisstanner and Armingeon (2020) using harmonized income surveys from the Luxembourg Income Study (LIS)
50-10 gross earnings ratio	Comparative Welfare States Data Set (Brady, Huber, and Stephens 2020), compiled from OECD Labour Market Statistics (data accessed 22 Jan 2019)
Digitalisation: ICT capital stock per employee in €1,000 (constant 2010 prices)	EU KLEMS Database 2019 Release; Streher (2019)
Bargaining coverage rate: Proportion of employees covered by collective (wage) agreements in force among employees with the right to bargain based on combined administrative and/or survey data sources	OECD/AIAS ICTWSS Database 2021
Centralisation of collective bargaining: A summary index of the degree of centralisation of collective bargaining. For a detailed explanation of how the measure is calculated, see the OECD/AIAS ICTWSS Database Codebook.	OECD/AIAS ICTWSS Database 2021

Type of coordination of wage setting: 6 = Government-imposed bargaining (incl. statutory controls in lieu of bargaining); 5 = Government-sponsored bargaining (this includes social pacts, provided they deal with wages); 4 = Inter-associational by peak associations; 3 = Intra-associational ("informal centralisation"); 2 = Pattern bargaining; 1 = Government sets signals (public sector wages, minimum wage); 0 = No specific mechanism identified.	OECD/AIAS ICTWSS Database 2021
Tertiary education: Proportion of 25-64 year olds with (at least) tertiary education	OECD (2022), Adult education level (indicator) (data accessed 25 May 2022)
Adjusted savings: education expenditure (% of GNI)	World Bank staff estimates using data from the United Nations Statistics Division's Statistical Yearbook, and the UNESCO Institute for Statistics online database
Public expenditure on active labour market measures (as a % of GDP)	OECD (2023), Dataset: Public expenditure and participant stocks on LMP (data accessed 19 Jan 2023)
Gross domestic spending on research and development (as a % of GDP)	OECD (2023), Gross domestic spending on R&D (indicator) (data accessed 19 Jan 2023)
Trade union density (percentage of employees)	OECD/AIAS ICTWSS Database 2021 (data accessed 19 Jan 2023)
Trade openness: (Exports + imports) as a % of GDP	OECD Annual National Accounts (data accessed 2 Nov 2022)
Private debt as a % of GDP	OECD Financial Indicators (data accessed 2 Nov 2022)
Unemployment rate (all persons; s.a.)	OECD Key Short-Term Economic Indicators (data accessed 3 Nov 2022)
GDP per capita (constant prices, constant exchange rates, OECD base year)	OECD Annual National Accounts (data accessed 2 Nov 2022)
Left government: Share of seats in parliament held by leftist parties in the most recent government as a percentage of all seats held by the government (cumulative score from 1946 to year of observation)	Comparative Welfare States Data Set (Brady, Huber, and Stephens 2020); see codebook for detailed underlying sources

Table A2. Variables and data sources for individual-level non-wage benefits analysis

Variable	Source
Non-wage benefits: 'With regard to your earnings from your main job, do they include advantages of any other nature (for instance, medical services, access to shops, etc.)?' (1 = Yes' 0 = No)	European Working Conditions Survey (EWCS) 2005, 2010 and 2015 waves
Digitalisation (industry-level): ICT capital stock per employee in €1,000 (constant 2010 prices)	EU KLEMS Database 2019 Release; Streher (2019)
Bargaining coverage rate (national-level): Proportion of employees covered by collective (wage) agreements in force among employees with the right to bargain based on combined administrative and/or survey data sources	OECD/AIAS ICTWSS Database 2021
Tertiary education: Highest level of education or training is the first or second stage of tertiary education (i.e., ISCED 1997 levels 5 or 6) (1 = Yes; 0 = No)	European Working Conditions Survey (EWCS) 2005, 2010 and 2015 waves
Gender (1 = Female; 0 = Male)	European Working Conditions Survey (EWCS) 2005, 2010 and 2015 waves
Age (1 = 15-34; 2 = 35-44; 3 = 45+)	European Working Conditions Survey (EWCS) 2005, 2010 and 2015 waves
Type of employment contract (1 = Contract of unlimited duration; 2 = Contract of limited duration; 3 = A temporary employment agency contract; 4 = An apprenticeship or other training scheme; 5 = No contract)	European Working Conditions Survey (EWCS) 2005, 2010 and 2015 waves
Establishment size: Number of employees working in the establishment (1 = 1; 2 = 2–9; 3 = 10–49; 4 = 50–249; 5 = 250+)	European Working Conditions Survey (EWCS) 2005, 2010 and 2015 waves

Equations estimated in the wage premia analysis

$$y_{jt} = \beta_0 + \beta_1 D_{jt} + \beta_2 C_{jt} + \beta_3 D_{jt} * C_{jt} + \mu_j + \theta_t + \varepsilon_{jt}, \quad (1)$$

and

$$y_{jt} = \beta_0 + \beta_1 D_{jt} + \beta_2 C_{jt} + \beta_3 D_{jt} * C_{jt} + \sum \beta_k Z_{jtk} + \mu_j + \theta_t + \varepsilon_{jt}, \quad (2)$$

where j = country and t = year. In both models, y_{jt} is the 90-50 gross earnings ratio, D_{jt} is digitalisation, and C_{jt} is the bargaining coverage rate. $D_{jt} * C_{jt}$ is the interaction term for the two main independent variables, which is crucial to testing our central theoretical proposition. Both models also include an intercept term, β_0, country fixed effects, μ_j, time fixed effects, θ_t, and an error term, ε_{it}. The second model also includes a vector of k control variables, represented by Z_{jtk}.

Equations estimated in the non-wage benefits analysis

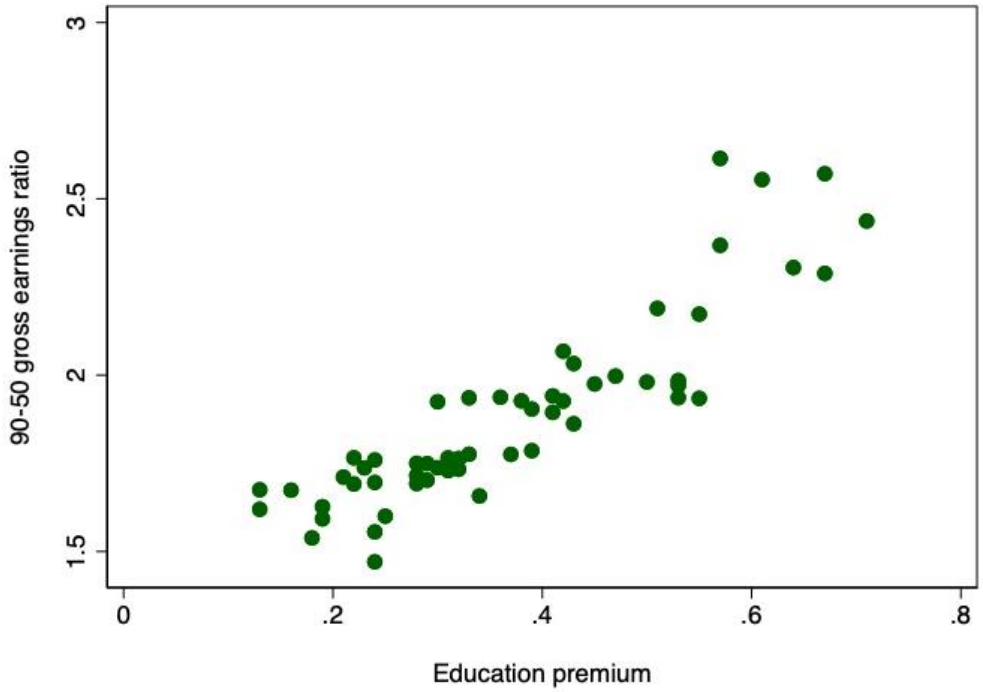
$$y_i = \beta_0 + \beta_1 D_{sjt} + \beta_2 T_i + \beta_3 D_{sjt} * T_i + \mu_j + \theta_t + \varepsilon_i, \quad (3)$$

and

$$y_i = \beta_0 + \beta_1 D_{sjt} + \beta_2 T_i + \beta_3 D_{sjt} * T_i + \sum \beta_k Z_{ik} + \mu_j + \theta_t + \varepsilon_i, \quad (4)$$

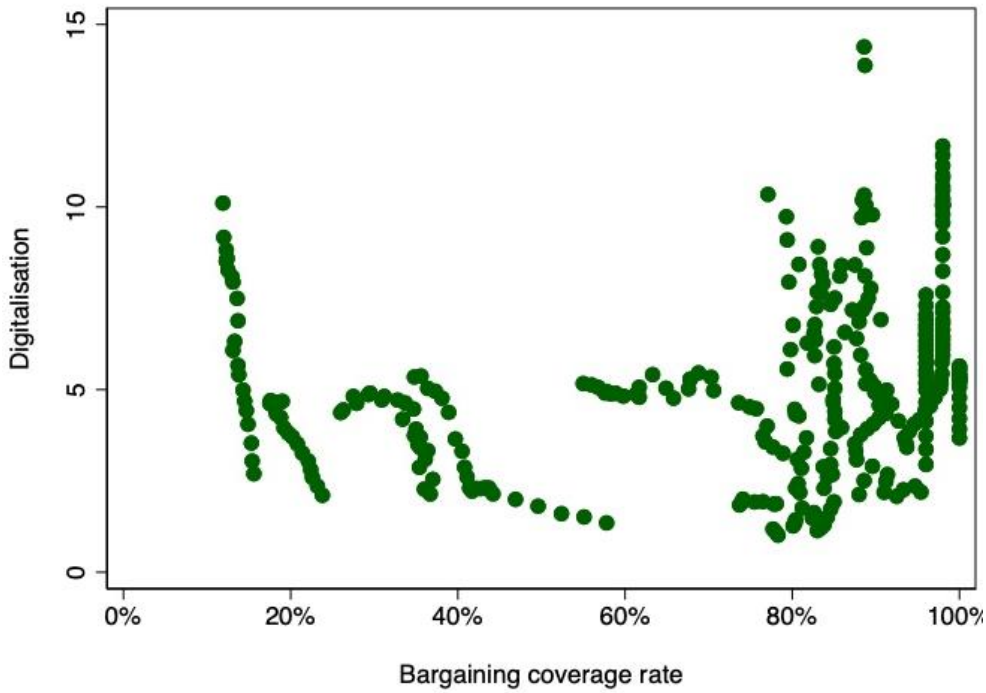
where i = individual, j = country, s = industry, and t = time period / survey wave. In both models, y_i is a binary variable for individuals' access to non-wage benefits. D_{sjt} is digitalisation at the industry level in country j in year t. T_i is a dummy variable for whether an individual has completed tertiary education and $D_{sjt} * T_i$ is the interaction term for tertiary education and digitalisation, which allows us to test whether there is a skill bias for non-wage benefits. Both models also include an intercept term, β_0, country fixed effects, μ_j, time fixed effects, θ_t, and an error term, ε_i. The second model also includes a vector of k individual-level control variables, represented by Z_{ik}.

Figure A1. Scatterplot of 90-50 gross earnings ratio and education premium – 15 countries, 1995 – 2017



Source: See Table A1.

Figure A2. Scatterplot of digitalisation and bargaining coverage rate – 15 countries, 1995 – 2017



Source: See Table A1.

Table A3. Wage premia analysis: Two-way fixed effect models – 15 countries, 1995-2017

	DV: 90-50 gross earnings ratio	
	(1)	(2)
Variables	No controls	All controls
Digitalisation	0.0317*	0.0508***
	(0.0171)	(0.0144)
Bargaining coverage rate	0.551	-0.138
	(0.553)	(0.166)
Digitalisation * Bargaining coverage rate	-0.0386**	-0.0285**
	(0.0172)	(0.0111)
Tertiary education		-0.00306
		(0.00204)
Active labour market policies		-0.00213
		(0.0367)
Research and development		0.0304
		(0.0380)
Trade union density		0.00220
		(0.00361)
Trade openness		-0.0562
		(0.105)
Unemployment rate		-0.0117**
		(0.00459)
Left government		0.000375
		(0.00531)
Private debt		2.46e-05
		(0.000265)
GDP per capita		1.38e-06
		(2.86e-06)
Constant	1.477***	1.874***
	(0.348)	(0.242)
Observations	225	203
R-squared	0.204	0.512
Number of countries	15	15
Country FE	YES	YES
Year FE	YES	YES

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

Table A4. Wage premia analysis: Alternative specifications

	DV: 90-50 gross earnings ratio			
	(1)	(2)	(3)	(4)
Variables	Linear time trend	Random effects	Prais-Winsten	All IVs lagged by one period
Digitalisation	0.0421***	0.0664*	0.0516***	0.0549***
	(0.0123)	(0.0355)	(0.00929)	(0.0103)
Bargaining coverage rate	-0.0733	0.621	-0.152	-0.0110
	(0.161)	(0.469)	(0.134)	(0.252)
Digitalisation * Bargaining coverage rate	-0.0273**	-0.128*	-0.0265***	-0.0343***
	(0.0122)	(0.0733)	(0.00942)	(0.0107)
Tertiary education	-0.00296	-0.00362	-0.00187	-0.00482**
	(0.00218)	(0.0107)	(0.00141)	(0.00183)
Active labour market policies	-0.00628	-0.0699	-0.00323	0.0260
	(0.0412)	(0.114)	(0.0210)	(0.0372)
Research and development	0.0253	-0.00793	0.0380**	-0.00286
	(0.0309)	(0.0940)	(0.0174)	(0.0344)
Trade union density	0.00146	-0.00832	-0.000106	0.00175
	(0.00407)	(0.00532)	(0.00247)	(0.00290)
Trade openness	-0.0803	-0.0635	-0.0210	0.0277
	(0.102)	(0.155)	(0.0478)	(0.130)
Unemployment rate	-0.00891*	4.71e-05	-0.0109***	-0.0121***
	(0.00438)	(0.0126)	(0.00316)	(0.00392)
Left government	-0.000817	0.00754	-0.00139	0.00231
	(0.00474)	(0.00697)	(0.00187)	(0.00365)
Private debt	3.44e-05	0.00163	-2.98e-05	-0.000228
	(0.000262)	(0.00141)	(0.000145)	(0.000283)
GDP per capita	1.88e-06	3.00e-06	1.04e-06	5.44e-07
	(2.32e-06)	(8.66e-06)	(2.56e-06)	(3.30e-06)
Time trend	0.000376			
	(0.00454)			
Constant	1.871***	1.393**	1.923***	1.912***
	(0.195)	(0.570)	(0.229)	(0.261)
Observations	203	203	203	196
R-squared	0.445	N/A	0.985	0.536
Number of countries	15	15	15	15
Country FE	YES	NO	YES	YES
Year FE	NO	YES	YES	YES

Prais-Winsten models have panel-corrected standard errors and ar(1) corrections. Standard errors in parentheses. For all other models, robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table A5. Wage premia analysis: Alternative independent variables

	DV: 90-50 gross earnings ratio	
	(1)	(2)
Variables	Alternative bargaining coverage variable	Alternative education variable
Digitalisation	0.0545***	0.0816***
	(0.0142)	(0.00389)
Bargaining coverage rate	-0.0584	0.136
	(0.0983)	(0.293)
Digitalisation * Bargaining coverage rate	-0.0350**	-0.0385***
	(0.0135)	(0.0112)
Tertiary education	0.00211	
	(0.00306)	
Education expenditure		0.0248*
		(0.0125)
Active labour market policies	-0.0318	-0.0215
	(0.0460)	(0.0301)
Research and development	0.0297	0.0400
	(0.0341)	(0.0284)
Trade union density	0.00531	0.00487
	(0.00572)	(0.00337)
Trade openness	0.199**	0.0232
	(0.0926)	(0.0526)
Unemployment rate	-0.0113*	-0.0168***
	(0.00556)	(0.00367)
Left government	-0.00112	0.0107***
	(0.00438)	(0.00317)
Private debt	0.000293	-0.000502**
	(0.000354)	(0.000171)
GDP per capita	8.40e-06	-3.77e-06
	(6.53e-06)	(2.45e-06)
Constant	1.194***	1.399***
	(0.394)	(0.358)
Observations	164	218
R-squared	0.632	0.492
Number of countries	15	15
Country FE	YES	YES
Year FE	YES	YES

Robust standard errors in parentheses. The alternative bargaining coverage variable is the same as the main bargaining coverage variable, just without missing values linearly interpolated. The alternative education variable is education expenditure (as a % of GNI).

*** p<0.01, ** p<0.05, * p<0.1.

Table A6. Wage premia analysis: Two-way fixed effect models (alternative dependent variable: education premium)

	DV: Education premium	
	(1)	(2)
Variables	No controls	All controls
Digitalisation	0.0246	0.00734
	(0.0141)	(0.0107)
Bargaining coverage rate	-0.274	-0.272
	(0.158)	(0.161)
Digitalisation * Bargaining coverage rate	-0.0267	-0.0214
	(0.0176)	(0.0128)
Tertiary education		0.00407
		(0.00369)
Active labour market policies		0.00879
		(0.0413)
Research and development		0.0142
		(0.0325)
Trade union density		0.00670*
		(0.00335)
Trade openness		-0.00709
		(0.0736)
Unemployment rate		0.00689**
		(0.00318)
Left government		0.00465
		(0.00462)
Private debt		-1.85e-05
		(0.000305)
GDP per capita		8.84e-06*
		(4.17e-06)
Constant	0.549***	-0.228
	(0.117)	(0.342)
Observations	79	74
R-squared	0.500	0.621
Number of countries	14	14
Country FE	YES	YES
Year FE	YES	YES

Robust standard errors in parentheses. The alternative dependent variable is the education premium from Weisstanner and Armingeon (2020).

*** p<0.01, ** p<0.05, * p<0.1.

Table A7. Wage premia analysis: Two-way fixed effect models (additional control variables: centralisation of collective bargaining and type of coordination of wage setting)

	DV: 90-50 gross earnings ratio
	(1)
Variables	All controls
Digitalisation	0.0483**
	(0.0180)
Bargaining coverage rate	0.00228
	(0.190)
Digitalisation * Bargaining coverage rate	-0.0347**
	(0.0144)
Tertiary education	-0.00349
	(0.00201)
Active labour market policies	0.0134
	(0.0322)
Research and development	0.0264
	(0.0338)
Trade union density	0.000884
	(0.00309)
Trade openness	-0.0850
	(0.108)
Unemployment rate	-0.0110*
	(0.00519)
Left government	0.00237
	(0.00435)
Private debt	-0.000150
	(0.000230)
GDP per capita	5.47e-06
	(5.30e-06)
Centralisation of collective bargaining	0.00902
	(0.0158)
Type of coordination of wage setting:	
1	0.0537
	(0.0535)
2	-0.0270
	(0.0455)
3	-0.00635

	(0.0510)
4	-0.119* (0.0580)
5	-0.0407 (0.0256)
6	(omitted)
Constant	1.732*** (0.297)
Observations	203
R-squared	0.577
Number of countries	15
Country FE	YES
Year FE	YES

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

Table A8. Wage premia analysis: Two-way fixed effect models (placebo test with 50-10 gross earnings ratio as the dependent variable)

	DV: 50-10 gross earnings ratio	
	(1)	(2)
Variables	No controls	All controls
Digitalisation	0.00884	0.00349
	(0.00945)	(0.0101)
Bargaining coverage rate	-0.625	-0.250
	(0.437)	(0.241)
Digitalisation * Bargaining coverage rate	0.00344	-0.0146
	(0.0133)	(0.0113)
Tertiary education		-0.00558*
		(0.00298)
Active labour market policies		0.00958
		(0.0215)
Research and development		-0.00668
		(0.0299)
Trade union density		-0.00397
		(0.00320)
Trade openness		0.150
		(0.130)
Unemployment rate		0.00124
		(0.00535)
Left government		-0.00508
		(0.00399)
Private debt		0.000272
		(0.000292)
GDP per capita		-9.90e-07
		(3.58e-06)
Constant	2.017***	2.076***
	(0.279)	(0.242)
Observations	225	203
R-squared	0.243	0.389
Number of countries	15	15
Country FE	YES	YES
Year FE	YES	YES

Robust standard errors in parentheses. Dependent variable is the 50-10 gross earnings from the Comparative Welfare States Data Set (Brady, Huber, and Stephens 2020).

*** p<0.01, ** p<0.05, * p<0.1.

Table A9. Digitalisation analysis: Two-way fixed effect models – 15 countries, 1995-2017

	DV: Digitalisation	
	(1)	(2)
Variables	No controls	All controls
Bargaining coverage rate	7.458*	11.52**
	(4.155)	(4.012)
Tertiary education		0.0543
		(0.0699)
Trade openness		0.596
		(1.532)
GDP per capita		0.000213*
		(0.000108)
Research and development		-0.0820
		(0.474)
GDP		-0.0170**
		(0.00710)
Constant	-2.763	-11.83**
	(3.137)	(4.561)
Observations	328	289
R-squared	0.756	0.763
Number of countries	15	15
Country FE	YES	YES
Year FE	YES	YES

Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table A10. Non-wage benefits analysis: Linear probability models (whole sample)

Variables	(1) No controls	(2) With controls
Digitalisation	0.00291*** (0.000309)	0.00255*** (0.000346)
Tertiary education	0.0362*** (0.00551)	0.0190*** (0.00634)
Digitalisation * Tertiary education	0.00190*** (0.000464)	0.00168*** (0.000512)
Constant	0.237*** (0.00761)	0.219*** (0.0157)
Observations	38,541	29,999
R-squared	0.143	0.165
Individual-level controls	NO	YES
Wave FE	YES	YES
Country FE	YES	YES

Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table A11. Non-wage benefits analysis: Linear probability models (sample split by bargaining coverage rate)

	Countries with below average bargaining coverage		Countries with above average bargaining coverage	
	(1)	(2)	(3)	(4)
Variables	No controls	With controls	No controls	With controls
Digitalisation	0.000760	0.000251	0.00324***	0.00279***
	(0.000464)	(0.000620)	(0.000355)	(0.000386)
Tertiary education	0.0490***	0.0415***	0.0307***	0.0105
	(0.00884)	(0.0111)	(0.00672)	(0.00752)
Digitalisation * Tertiary education	0.00274***	0.00376***	0.00172***	0.00133**
	(0.000961)	(0.00127)	(0.000521)	(0.000556)
Constant	0.0739***	0.0910***	0.209***	0.179***
	(0.00690)	(0.0205)	(0.00834)	(0.0188)
Observations	11,918	8,495	26,623	21,504
R-squared	0.023	0.049	0.118	0.145
Individual-level controls	NO	YES	NO	YES
Wave FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES

Robust standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table A12. Non-wage analysis: Logistic regression models (whole sample)

Variables	(1) Baseline model	(2) With controls
Digitalisation	0.0156*** (0.00162)	0.0135*** (0.00185)
Tertiary education	0.224*** (0.0325)	0.121*** (0.0373)
Digitalisation * Tertiary education	0.00797*** (0.00270)	0.00625** (0.00302)
Constant	-1.480*** (0.0451)	-1.731*** (0.116)
Observations	38,541	29,999
Individual-level controls	NO	YES
Wave FE	YES	YES
Country FE	YES	YES

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

Table A13. Non-wage analysis: Logistic regression models (sample split by bargaining coverage rates)

	Countries with below average bargaining coverage		Countries with below average bargaining coverage	
	(1)	(2)	(1)	(2)
Variables	Baseline model	With controls	Baseline model	With controls
Digitalisation	0.0102**	0.00743	0.0158***	0.0138***
	(0.00507)	(0.00619)	(0.00174)	(0.00196)
Tertiary education	0.573***	0.497***	0.158***	0.0528
	(0.0814)	(0.0998)	(0.0348)	(0.0396)
Digitalisation * Tertiary education	0.0138**	0.0166*	0.00759***	0.00551*
	(0.00670)	(0.00855)	(0.00290)	(0.00314)
Constant	-2.630***	-2.572***	-1.495***	-1.811***
	(0.0971)	(0.288)	(0.0473)	(0.123)
Observations	11,918	8,495	26,623	21,504
Individual-level controls	NO	YES	NO	YES
Wave FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

Table A14. Non-wage benefits analysis: Linear probability models (whole sample, with individual- and national-level controls)

Variables	(1) With controls
Digitalisation	0.00258*** (0.000352)
Tertiary education	0.0152** (0.00644)
Digitalisation * Tertiary education	0.00142*** (0.000524)
Constant	0.904*** (0.320)
Observations	29,168
R-squared	0.181
Individual-level controls	YES
National-level controls	YES
Wave FE	YES
Country FE	YES

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

Table A15. Non-wage benefits analysis: Linear probability models (sample split by bargaining coverage rate, with individual- and national-level controls)

	Countries with below average bargaining coverage	Countries with above average bargaining coverage
	(1)	(2)
Variables	With controls	With controls
Digitalisation	0.000702	0.00277***
	(0.000621)	(0.000389)
Tertiary education	0.0382***	0.0105
	(0.0113)	(0.00750)
Digitalisation * Tertiary education	0.00265**	0.00118**
	(0.00129)	(0.000565)
Constant	-0.128	-0.724
	(0.134)	(0.666)
Observations	7,664	21,504
R-squared	0.035	0.158
Individual-level controls	YES	YES
National-level controls	YES	YES
Wave FE	YES	YES
Country FE	YES	YES

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.