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The effect of computerisation on the wage share in United Kingdom workplaces

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Abstract

This historical paper analyses the distributional consequences of computerisation on the wage share of income in United Kingdom (UK) workplaces in the first decade of this century. The reasons why computerisation might increase a firm's income but reduce the share assigned to wages are still not well understood. The uniquely rich Workplace Employment Relations Survey (WERS) 2004–2011 includes firm-level measures of the main production inputs and outputs, and thus allows an analysis of the main mechanisms through which increased computer usage influenced the wage share of income in UK workplaces over this period. This analysis shows that the proportion of employees using computers impacted the wage share in ways that were at odds with two mainstream views: that computers complement capital, and that labour can be easily replaced by capital. The results show that the proportion of employees using computers reduced the wage share by disproportionally increasing the productivity of the least skilled employees, who were not proportionally compensated for their increase in productivity. The stability of the wage share, over the period of interest, is explained by the rise in a workplace's share of professional employees and by a rise in work effort. This positive contribution to the wage share was counteracted by an increased share of employees using computers and by a reduction in the share of employees whose pay was negotiated by unions, thereby contributing to a decline in the wage share of firm income.

JELcode: J31

Keywords

Income distribution, technological change, industrial relations, political economy

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Introduction

Since the 1970s, the increasing gap between growth in labour productivity and wages, resulting from the sluggish growth of the latter, was accompanied by a rise in the national income share of capital and particularly corporate profits. The result has been a decline in the wage share of aggregate income in many Western societies. In the Group of Seven (G7) countries, the wage share of income has declined by an average of two percentage points per decade, starting from 70% in 1970 (Adrjan, 2018). Possible reasons for this decline are the changing composition and declining level of government spending (Huber and Stephens, 2014; Pensiero, 2017; Stockhammer, 2017), globalisation (Kanbur, 2000; Stockhammer, 2009), weakening bargaining power of unions (Bengtsson, 2014; Kristal, 2010) and technological change (European Commission [EC], 2007; International Monetary Fund [IMF], 2007).

There is controversy regarding the reasons why information and communication technologies (ICTs) might help increase the divide between the profit and wage shares of income. Some leading economists theorise that ICTs have increased the productivity of capital more than that of labour, leading to an increase in capital intensity, which in turn caused labour's share of income to decline (Karabarbounis and Neiman, 2014; Piketty, 2014).[1] The capital augmenting (or biased) nature of ICTs, in combination with a high substitutability between capital and labour inputs, has led firms to increase the use of capital relative to labour inputs. Against this view, Lawrence (2015), Acemoglu (2003), Wei (2014) and Young (2010) argue that technology is labour augmenting (increasing the productivity of labour inputs more than that of capital) and that labour cannot be easily substituted by capital. The latter hypothesis implies that the increase in productivity since the 1980s has disproportionally contributed to profits despite depending on labour contributions as much as on technological innovations. Using a power relations approach, Kristal (2010, 2013) challenged the idea that ICTs' role in the wage share is accounted for by productivity-enhancing mechanisms and argued that ICTs erode the wage share by facilitating the anti-union actions of management, and by polarising the workforce with respect to skills, thus undermining worker solidarity.

Most empirical research on economic inequalities, including within the heterodox tradition, has overlooked an alternative interpretation of the role of ICTs in production processes – that ICTs are labour augmenting and that the possibilities of substitution between labour and other production inputs are limited. At present, there is no conclusive evidence as to whether ICTs have had a significant impact on the wage share in the United Kingdom (UK) and whether the mechanisms through which ICTs affected the wage share align more with the capital augmenting or labour augmenting view of technological change (IMF, 2007; Kristal, 2010, 2013; Stockhammer, 2017). Moreover, data limitations have prevented extant research on the wage share from analysing the combined effect of ICTs and management techniques on the wage share. Labour economics research focusing on management practices has suggested that over the last 30 years in the UK, employees have been under pressure to expend increasing levels of effort (Felstead and Green 2017; Green, 2006). Yet, I am aware of no study analysing whether management practices mediate the effect of ICTs on income inequality. This paper's contribution lies in analysing the extent of the impact of the uptake of computers on wage share and identifying the main mechanisms accounting for the role of computerisation. The present analysis uses a particular data set available for the period 2004 to 2011 – the Workplace Employment Relations Survey (WERS) – to analyse the role of a wide set of production inputs, including labour inputs (share of skilled, intermediate and low skilled employees), management practices (intensity of monitoring, just-in-time techniques, employee involvement, improvement groups, workplace work effort) and capital investment, while controlling for union activity, scope of the market, firm performance, and industry differences. This rich dataset allows analysis of, and potential generalisation from, the question of whether computers were labour or capital augmenting, and an exploration of exploration of new mechanisms brought into play, that is, whether the use of computers increased the efficiency of management practices in a way that benefited profits or wages.

The firm is the natural unit to analyse those mechanisms. The way in which income is shared between capital and labour is the result of production and wage bargaining processes occurring in the UK at the firm level. While most analyses of the wage share of firms' income have been conducted at the country and sector level, this paper contributes to the stream of research using firms as the unit of analysis (Adrjan, 2018; Autor, et al., 2017; Autor et al., 2020; Dinlersoz and Wolf, 2018; Growiec 2012; Siegenthaler and Stucki, 2015).

A workplace analysis of wage share has several advantages. First, most analyses imply that the main sources of variation in national wage share are within-firm and that the effects of technology, globalisation and labour relations institutions are equal for all firms (Gollin, 2002; Gordon, 2005; Piketty, 2007; Piketty and Saez, 2007; Zuleta and Young, 2007). Yet conversely, Autor et al. (2017) show that wage share has a large element of between-firm variation.

Additionally, a firm-level analysis overcomes major measurement issues that affect most literature on wage share of income. This paper uses the employees' share of a workplace's net income (after intermediate costs) as the measure of wage share. Aggregate definitions of wage share somehow arbitrarily assign capital and labour incomes to entrepreneurs, self-employed and employees, who might receive incomes both from owning capital and from their labour. Firm-level analysis avoids this problem.

I use data from the uniquely rich employer–employee matched Workplace Employment Relations Study (WERS). Using the 2004 and 2011 surveys, I construct a repeated cross-sectional sample of firms, constructing measures of income level (which is the chosen measure of output) and income share, management practices and employee characteristics. The richness of information on firms is ideal for an analysis like the one proposed, focused on differences between firms and changes over time. The analysis remains relevant to today's economy as computers are forms taken by automated and digitalised production processes. Nevertheless, the sample covers a specific period of 11 years and cannot be used to make generalisations about trends in the longer term. The literature review that follows focuses on the main mechanisms used to explain the association between computers and income inequalities. I then present the statistical methods used, which include estimation of both a production and distribution function. The analysis centres on an estimation of the impact of computers on income level and wage share of income and, the mechanisms that account for this impact. Finally, I draw a conclusion of the results for the wage share.

Literature review

In order to derive the key explanatory variables allowing quantification of the consequences of the increased use of computers on wage share, a literature review provided four main themes for exploration. Has computer-based technological change been biased towards capital or labour? Has it been biased towards skilled or less skilled occupations? What has been the effect of management practices? What other control factors need to be considered? These themes are discussed in turn in *Is computer technology biased towards capital or labour?*, *Is computerisation biased towards skilled or less skilled occupations?*, *Computers and management practices*, *Control factors*, and were used as the basis for deriving the independent and control factors used in the statistical analysis.

Is computer technology biased towards capital or labour?

In line with the mainstream hypothesis, some leading economists theorise that ICTs increase the productivity of capital more than that of labour (i.e. are capital augmenting), increasing the quantity of capital relative to the quantity of labour, which in turn causes the labour share of income to decline (Karabarbounis and Neiman, 2014; Piketty, 2014).[2] Some processes such as the relocation of labour-intensive tasks in less advanced countries and the global decline in the relative price of investment goods are in line with the capital augmenting hypothesis. Piketty and Zucman (2013) link the concentration of capital to the saving to growth rate. In the presence of high substitutability and capital augmenting technology, a low or constant growth rate leads to a growing capital to output ratio and hence to a decline of the wage share. Karabarbounis and Neiman (2014) relate the global decline in the relative prices of investment goods that started in the 1980s to the rise in the capital-labour ratio, which in turn reduced labour's share of income. The capital augmenting hypothesis inspired the finding in the IMF World Economic Outlook (2007), that overall, technological progress is a larger contributor to the fall in the wage share of income than changes in labour market policies.

The hypothesis of an inverse relationship between capital intensity and labour share is at odds with the literature that focuses on estimating the elasticity of substitution between capital and labour. While the exact value of the elasticity is still debated, evidence overall shows that production processes and technology have increased labour's productivity more than they increased capital's (labour augmenting technology) and that ICTs, rather than substituting labour, complement it (Chirinko, 2008; Wei, 2014; Young, 2010).

Therefore, the available evidence supports the heterodox hypothesis that ICTs are labour augmenting, implying that they contribute to increase the productivity of labour more than that of capital and hence exert a pressure to maintain or increase the demand for labour. However, a positive effect on the productivity of labour does not automatically translate into a larger wage share. When labour and capital are complements, the demand for labour – due to the bounded nature of the capital to labour ratio – cannot increase beyond a certain threshold, without an adverse effect on the efficiency of production. The result is that the demand for labour does not increase sufficiently to match its enhanced productivity (Lawrence, 2015; Oberfield and Raval, 2014). The computer-enhanced labour productivity is therefore transferred to capital's return rather than to wages, thus reducing the wage share. The paper hypothesises, in line with the heterodox perspective, that computers improve the productivity of labour more than that of capital but receive a share of income which does not match its productivity.

Is computerisation biased towards skilled or less skilled occupations?

The effect of computers on the productivity of and demand for labour is likely to vary across skilled and less skilled occupations The skill-biased technological change (SBTC) hypothesis posits that computers complement workers in either high or low skill occupations, rather than those with mid-level skills (Acemoglu and Autor, 2011). The starting point of this skill polarisation perspective is the observation of an increasing return to skills – that is, university degrees – in many western countries from the mid-seventies to the 1980s despite the secular increase in the supply of university educated workers (Acemoglu and Autor, 2011; Greiner et al., 2004). This suggests that technological change, which was driven by the spread of computers in workplaces, increased the productivity of skilled workers more than those of less skilled workers. More recently, from the 1980s to 2005, in the United States (US) there was a rise in both the wages of skilled occupations and the wages of occupations at the bottom of the skill distribution, performing tasks which are not easily displaced by computers and rely on dexterity, interpersonal relationships and physical proximity, such as service and manual occupations. Conversely, the wages of middle skill occupations performing mainly routine codifiable tasks declined (David and Dorn, 2013). Reshef (2013) documents that in the US from 1963 to 2005 the average efficiency of less skilled occupations outgrew that of college graduates in the service sector. Gregory et al. (2016), show that the effect of technological change in replacing routine tasks – called routine-replacing technological change (RRTC) – can help increase the demand for low- and middle-skill groups indirectly by reducing the cost of production. While RRTC reduced employment for middle-skill occupational groups, this reduction was more than offset by the effect of RRTC in creating new demand through reducing production costs. This increase in product demand, in turn, raised income which was also spent on low-tech products favouring local labour demand.

This literature implies that computers can have diverse effects on the productivity of and demand for different occupations. The empirical analysis will investigate which occupation types – professional, intermediate or less skilled – experienced the greatest computer-induced productivity increase.

Computers and management practices

Computerisation can steer work practices towards high effort and efficiency. Those changes, as any change that affects efficiency in production, are likely to affect the wage share. Hence this study explores the combined effect of computers and management practices on the wage share of income. There is evidence of work intensification in UK workplaces (Felstead and Green, 2017; Green et al., 2021) and of the use of digital technology to pass competitive pressure on to workers (Burchell et al., 1999). This process is thought to have been fostered by the weakening of unions (Green and Mcintosh, 2001), by the enhanced capacity of employers to measure, motivate and discipline effort, and, crucially for our analysis, by the effort-biased nature of computers (Green, 2004). It can be hypothesised that computers may raise the productivity of high effort workers relative to that of other factors of production. Software, computing power along with efficient management practices enhance efficiency in allocating work schedules and workflows, enabling a closer match between the fluctuating demand of customers and work effort. Accordingly, the combination of computer usage and employees effort may have significantly enhanced firm profits.

In recent decades innovations in work organisation aimed at improving the efficiency of production processes and fostering individuals' responsibility and flexibility have been diffused across countries, along with new information technologies (Jiang and Messersmith, 2018; Jiang et al., 2012; Patel et al., 2013; Shin and Konrad, 2017). Computers may enhance the efficiency of such management practices in several ways. They may make just-in-time production, total quality management and involvement practices more efficient in allocating labour inputs, thus increasing output levels. Second, computers may also increase the precision of the managerial monitoring of effort and output (Green, 2004), eroding workers' bargaining power and reducing the need to incentivise workers through above-market wages. Third, more recently, new forms of IT platform-mediated gig- and crowd-work transfer planning insecurity from managers to workers, render performance evaluation non-transparent, allow payment only for fragmented tasks and undermine worker bargaining power (Pfeiffer and Kawalec, 2020). The analysis will therefore assess whether wage levels have increased in step with the growth in firm income levels associated with the combined use of new management practices and computer technology.

Control factors

Recent studies of the bargaining relations between capital and labour have focused on the role of globalisation in strengthening the position of capital. Globalisation is thought to have placed domestic workers in competition with workers from abroad and weakened the influence of domestic political forces on domestic wages and work conditions (Kanbur, 2000; Stockhammer, 2017). Throughout the analysis, I shall control for measures of the scope of the firm's market as a proxy for the effect of globalisation.

In the United Kingdom the institutions and practice of collective bargaining have eroded over the last four decades. Union density, and the involvement of unions in workplace regulation, have declined considerably (Achur, 2010; Millward et al., 2000). Firms increasingly set pay without negotiation with unions or, bargained at workplace level rather than at a higher or mixed level (Addison et al., 2013; Van Wanrooy et al., 2013). In workplaces where unions have voice, productivity deals feature prominently in bargaining agreements in several sectors (Andrews and Simmons, 1995; Elger, 1990; Tomaney, 1990). Such bargaining agreements will shift income share towards profits if agreed pay rises are more than compensated for by the higher productivity conceded by employees during bargaining. The negative effect of unions on profitability in the UK has been declining since the 1980s, yet there is conflicting UK evidence about whether the effect is still statistically significant (Blanchflower and Bryson, 2009; Bryson et al., 2011). My analysis will control for the share of employees with pay negotiated by unions.

Finally, I shall control for the financial performance of the workplace, as the way in which the income is distributed between wages and profits might depend on financial resources available.

Modelling strategy

This paper contributes to the literature on wage share with an analysis of the role of computers in both redistributive and production processes. Additional supplementary data are presented in Supplementary Appendix A. Only a few studies on the distributional consequences of ICTs analyse the underlying production mechanisms and thus offer estimates on their own of the extent of bias of new technologies towards capital and labour (Dinlersoz and Wolf, 2018; Lawrence, 2015; Oberfield and Raval, 2014). I directly tested the hypotheses regarding the mechanisms underlying the hypothesised distribution processes. If the effects of any given factor on the workplace's income level and the share of income that it retains are consistent, it can be concluded that the mechanisms of redistribution match the contribution of that factor to productivity; otherwise, if there is discrepancy between the two effects, it means that part of the contribution of the factor to productivity translates into either the employee's or firm's rent.

The statistical model is a log-log linear regression which uses a binary variable for the survey year and interaction terms to test the hypotheses regarding the combined effect of computers and other production factors.

I model the production function using the translog function, which is linear in its parameters, accommodates both linear, quadratic and interaction terms, and can use more than two factor inputs (Christensen et al., 1973; Supplementary Appendix B). I analyse the mechanisms accounting for the effect of share of employees using computers on the wage share by estimating its bias with respect to capital and labour inputs and the elasticity of substitution between computers and capital and labour inputs (Supplementary Appendix B).

Throughout the analysis, I used the publicly provided weights to take into account the sampling design, which resulted in larger workplaces and workplaces from less populated industries being oversampled. In addition, I use a weight to adjust for the differences in sample sizes between the 2004 and 2011 surveys.

Results

Table 1 presents the main results of the regression models of income level and wage share. The model specification covers the key production inputs discussed so far – labour inputs

Table 1. Effect of workplaces' characteristics on the income level and share (wage share). Elaborations from WERS 2004 and 2011. Beta coefficients and standard errors in parentheses.

	Wage share (log)		Income level (log)	
	Model 1	Model 2	Model 3	Model 4
Share of employees using computers (log)	−0.80***	−0.51*	1.54***	1.06*
	(0.17)	(0.2)	(0.42)	(0.48)
Number of employees (log)	0.04	0.05	0.93***	0.90***
	(0.04)	(0.04)	(0.1)	(0.1)
Share of professional employees (log)	0.59**	0.64**	−0.14	0.23
	(0.2)	(0.21)	(0.49)	(0.53)
Share of intermediate employees (log)	0.79***	0.82***	−0.92	0.34
	(0.24)	(0.25)	(0.57)	(0.87)
Workplace's work effort (log)	0.99**	0.86**	0.91	0.76
	(0.31)	(0.32)	(0.75)	(0.73)
Monitoring (log)	−0.18	−0.12	0.8	0.99*
	(0.21)	(0.22)	(0.5)	(0.49)
Share of employees with pay negotiated by unions (log)	0.19**	0.18**	−0.13	−0.15
	(0.06)	(0.06)	(0.15)	(0.14)
Employees' involvement in decisions (log)	−0.09	−0.17~	−0.06	−0.05
	(0.09)	(0.1)	(0.23)	(0.22)
Improvements groups	−0.20~	−0.18	0.39	0.47~
	(0.11)	(0.11)	(0.26)	(0.26)
Just−in−time	−0.02	0.04	−0.45*	−0.38~
	(0.09)	(0.09)	(0.21)	(0.21)
UK's market share (log)	−0.14*	−0.08	0.44**	0.41**
	(0.06)	(0.06)	(0.15)	(0.15)

(continued)

Table 1. (continued)

	Wage share (log)		Income level (log)	
	Model 1	Model 2	Model 3	Model 4
Workplace faces competition from overseas	0.11	0.1	0.1	0
	(0.09)	(0.09)	(0.21)	(0.21)
Financial performance (log)	−0.36*	−0.42**	0.51	0.73*
	(0.15)	(0.15)	(0.36)	(0.34)
Share of professional employees (log)*Share of employees using computers (log)		3.97***		−9.17***
		(0.73)		(1.81)
Share of intermediate employees (log)*Share of employees using computers (log)		3.09**		−7.15**
		(0.97)		(2.68)
Workplace's work effort (log)*Share of employees using computers (log)		−2.22~		
		(1.13)		
Monitoring (log)*Share of employees using computers (log)		0.01		
		(0.77)		
Share of employees with pay negotiated by unions (log)*Share of employees using computers (log)		0.51*		
		(0.23)		
Employees' involvement in decisions (log) * Share of employees using computers (log)		−0.62~		
		(0.33)		
Improvement groups*Share of employees using computers (log)		−0.98*		
		(0.47)		
Just−in−time*Share of employees using computers (log)		−0.05		
		(0.34)		
Capital per employee (log)			0.28***	0.24***
			(0.05)	(0.05)

(continued)

Table 1. (continued)

	Wage share (log)		Income level (log)	
	Model 1	Model 2	Model 3	Model 4
Share of employees using computerˆ2 (log)				4.04~
				(2.24)
Capital per employeeˆ2 (log)				0.05***
				(0.01)
Share of professional employeesˆ2 (log)				5.90**
				(2.21)
Share of intermediate employeesˆ2 (log)				0.28
				(3.22)
Capital per employee (log) *Share of employees using computers (log)				−0.63**
				(0.2)
Share of professional employees (log)*share of intermediate employees (log)				9.01*
				(3.93)
Share of professional employees (log)*Capital per employee (log)				0.74**
				(0.23)
Share of intermediate employees (log)*Capital per employee (log)				0.84**
				(0.27)
2011	0.05	0.03	0.09	0.11
	(0.08)	(0.08)	(0.2)	(0.19)
Constant	−0.35	−0.40~	−2.30***	−2.74***
	(0.24)	(0.23)	(0.57)	(0.59)
Observations	694	694	679	679
Adjusted R−squared	0.09	0.13	0.28	0.32

~ p<0.10, * p<0.05, ** p<0.01, *** p<0.001
Other control variable: industry category
Income level and capital per employee are measured in thousands of pounds

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(total number of employees, proportion of professional employees, proportion of intermediate employees), the level of computerisation (proportion of employees using a computer), capital inputs[3] (capital per employee) and management practices, and the control variables. Supplementary results can be found in the Supplemental File Appendix. Supplementary Appendix Table C1 presents the mean and standard deviation of the main variables for the two surveys, the daily gross wage per employee and the daily income per employee in pounds, adjusting for inflation. I experimented with different model specifications which are not shown, using additional measures of human resource practices, such as performance related-pay and profit-related pay. Those additional variables did not show a significant effectiveness and did not alter the estimates of the remaining variables, hence were excluded from the presented results. Therefore, the selected model specifications tend to be parsimonious when the exclusion of variables does not lead to a loss of information. Results of regression models when the groups of independent variables are added progressively in a stepwise fashion are presented in Supplementary Appendix Tables D.1 and D.2 while Supplementary Appendix Table E1 presents an estimation of the contribution of different factors to the stability of the wage share over the period.

Model 1 in column 1 and Model 3 in column 3 of Table 1 present the results of the baseline regression model for wage share and income level using the complete list of covariates. The second column presents the results of regression model for the wage share allowing the level of computerisation to interact with the main production inputs. Model 3 presents the baseline production function with no interaction terms and Model 4 (column 4) presents the translog production function, which includes quadratic and interaction terms between the main production inputs (proportion of professional employees, proportion of intermediate employees, capital per employee, computerisation).

The degree of computerisation shows opposite effects on the level and share of income. A 1% increase in the share of employees using computers is associated with a reduction of the wage share of 0.8% points ($p < 0.001$) in Model 1. Conversely, the share of employees using computers is associated with a higher level of income, with a 1% increase in computerisation being associated with a 0.7% income increase[4,5] ($p < 0.1$) (corresponding to a 1.1% in the parameter estimate in Table 1, $p < 0.05$, Model 4). In other words, computers make workplaces more productive, yet most of this increase is reaped by profits. The reasons for this are explored below in the analysis of the elasticity of substitution and complementarity between inputs.

The number of employees does not show a substantial or statistically significant association with wage share, while it has a positive association with the income level (0.9% increase, $p < 0.001$). The share of professional employees in the workforce shows a positive and significant association with wage share (0.6%, $p < 0.1$) and a positive and non-significant association with income level (0.6% income elasticity,[6] and 0.2% in the regression model, not significant at the conventional levels, Model 4).

The share of intermediate employees is associated with a larger wage share (0.8%, $p < 0.001$). The variable is also positively associated with income level (0.8% income increase,[7] and 0.3% in the regression model), but the estimates are not statistically significant.[8]

Mode 2 introduces an interaction between the share of employees using computers and the share of professional and intermediate employees. The results show that workplaces with a higher share of professional and intermediate employees, tend to share more of their income with their workforce than workplaces with fewer professionals (4% more, $p < 0.001$) and fewer intermediate employees (3% more, $p < 0.01$). The interaction between the share of employees using computers and professional employees has opposite effects on the income level. The share of employees using computers increases the income level of all workplaces and especially of those where there is a larger share of less skilled employees with respect to professional employees (9% increase,[9] $p < 0.001$) and intermediate employees (7% increase,[10] $p < 0.01$).

Demanding greater work effort from employees augments the workforce's wages more than profits or income level. Demanding greater effort was associated with a higher wage share (1% more in Model 1 ($p < 0.01$) and 0.9% more in Model 2 ($p < 0.01$)) and a larger income level, although the latter estimate was not significant. The interaction term in Model 2 shows that in highly computerised workplaces the relationship between work effort and wage share become negative (−2% of the wage share, $p < 0.1$). Computers tend to turn work effort into higher profits.

Workplaces with more intensive monitoring of their employees generated higher levels of income (1% increase, 0.05). The coefficient regarding the wage share was negative and noteworthy, but non-significant. The coefficient regarding monitoring remained non-significant even when the variable was interacted with the level of computerisation.

Union activity was found to be related to a larger wage share. When the share of employees with pay negotiated by unions increased by 1%, the wage share became 0.2% points larger ($p < 0.01$). The interaction term between computers and union activity in Model 2 shows that highly computerised workplaces especially benefited from union activity (0.5%, 0.05). There was a negative but non-significant association between union activity and the income level.

Involving employees in decisions shows a negative association with the wage share, which was non-significant (−0.1) in Model 1 and significant in the Model 2 with all the interaction terms (0.2, $p < 0.1$). The interaction term in Model 2 shows that computers turned the involvement of employees in decisions into a lower wage share (−0.62, $p < 0.1$). The association between decision making and income level was small, negative and non-significant. Improvement groups showed similar results to those of employee involvement, a negative association with wage share (−0.2, $p < 0.1$) and a positive association with income level (0.5, $p < 0.1$). When combined with computers, improvement groups show even larger negative effects on the wage share (−1%, $p < 0.05$).

Just-in-time techniques show a weak, mixed and non-significant association with wage share, and a negative but significant association with income level (−0.4, $p < 0.1$). The interaction with computers does not change these results significantly.

The models control for the effect of globalisation and a firm's financial performance. The UK share of the domestic market has a negative association with wage share (−0.1, $p < 0.05$) in Model 1 and a negative, smaller and non-significant association in Model 2. The association with income level is positive (0.4 in Model 4, $p < 0.01$). The results indicate that firms which produce for the domestic market tend to offer services and goods with a larger value added, yet they share less income with their employees. The other measure of globalisation – facing competition from abroad – shows a positive, yet non-significant association with wage share and income level.

The financial performance of the workplace has a negative and significant association with wage share (−0.4 in model 4, $p < 0.05$) and a positive one with income level (0.7, $p < 0.05$). The better a workplace's financial performance the greater their income level but the lower their wage share.

In order to investigate the mechanisms that explain the negative effect of computers on wage share, I now analyse the possibilities of substitution between computers and labour, and the ability of computers to enhance the productivity of labour and other inputs.

The findings regarding the effectiveness of the share of employees using computers from the analysis of both the wage share and the income level suggest that computers make workplaces with a larger proportion of less skilled employees more productive, yet this increased productivity is mostly reaped by profits. The productivity of workplaces with a higher share of professional and intermediate employees benefits less from computerisation, yet such workplaces share more of their income with their employees.

While the use of computers across the workforce increases the productivity of the least skilled employees, it is negatively related to the productivity of capital. Therefore, the results support the view that computers augment mainly the productivity of less skilled labour.

The measure of elasticity of substitution between the share of employees using computers and the share of professional and intermediate employees is negative (respectively −19[11] and −11[12]), indicating that the distribution of the three main groups of occupations – professional, intermediate and least skilled – and the share of employees using a computer complement each other. This means that it is not possible to increase or reduce the incidence of one of those inputs without changing the others too.

The elasticity of substitution between the share of employees using computers and capital is negative and small (−2.2),[13] suggesting a complementary relationship between the two inputs, although to a smaller extent than that between occupations and computers.

The evidence presented so far suggests that the negative impact of the share of employees using computers on wage share, is accounted for by the combination of the labour augmenting nature of computers – which increases the productivity of workplaces where there is larger proportion of least skilled employees – and the high level of complementarity between employee skill levels and degree of firm use of computer technology. Workplaces would be incentivised to increase the share of the least skilled employees, yet the complementarity between the different skill groups and computers prevents this pressure from turning into a higher demand for any particular skill group. As a result, the increased productivity of highly computerised workplaces is transferred to profits mostly. While the value of elasticity between computer, capital and labour inputs is still debated, the results are broadly consistent with previous research showing that production processes and technology have increased labour's productivity more than they increased capital's (labour augmenting technology) and that computers, rather than substituting labour, complement it (Chirinko, 2008; Wei, 2014; Young, 2010). In addition, computers render the techniques of work organisation that involve the participation of employees (employees' involvement and improvement groups) more effective at increasing the profit share (and reduce the wage share). Conversely unions are more effective at increasing the wage share in more computerised workplaces.

Conclusions

The article used a firm-level dataset to analyse whether computers contribute to reducing the wage share of income and to assess the reasons for this effect. The regression analyses confirm positive relationships between the share of employees using computers and income level, and a negative relationship with wage share. Computers make workplaces more successful at increasing the income level, but this advantage is largely beneficial to profits. This analysis suggests a heterodox interpretation of the decoupling of the productive and redistributive effect of computers. In contrast with the view that the capacity of computers to make other factors more productive is biased towards capital and professional employees (IMF, 2007; Karabarbounis and Neiman, 2014; Piketty, 2014), this analysis suggested that the share of employees using computers increased disproportionally the productivity of low skilled occupations relative to other factors of production. The results showed that there was complementarity between the share of employees using computers and low skilled employees. This complementarity in the technology of production processes prevents computer-enhanced productivity from translating into a higher demand for labour inputs. The result is that computer-enhanced productivity mostly increases profits.

The inclusion of management practices as production inputs sheds light on aspects of the wage share which have not to my knowledge been analysed before. Intensity of effort, an aspect of the relationship between employees and employers which is difficult to define in job contracts (Bowles and Jayadev, 2006; Bowles and Gintis, 1988), is positively associated with the wage share. The analysis showed that workplaces demanding a more intense level of effort reward their employees with a larger wage share. A possible reason is that workplaces that require employees to expend more effort are more dependent on incentives, including higher wages.

Regarding monitoring, workplaces that exert greater control over employees tasks, despite using larger resources to supervise employees, achieve both a larger income and a lower wage share (the effect size was substantial but non-significant). These findings regarding work effort and monitoring suggest that a relevant part of the bargaining between employees and employers occurs at the individual level and involves non-contractual aspects of the job.

In addition, computers were shown to interact positively with work effort and some of the management techniques analysed, such as employee involvement and improvement groups, but not with monitoring. Highly computerised workplaces tend to turn those practices which rely on the participation of employees into larger profits.

The substantial stability of the wage share over the period is the result of the opposite effects of the share of professional employees and work effort on the one hand and the share of employees using computers and the share of employees with pay negotiated by unions on the other. The negative contribution of the share of employee using computers and the share of employees with pay negotiated by unions was compensated by the increased share of professional employees and the increased requirement to expend effort. Transformation of production processes via computers has had diverse effects on the wage share. This transformation increased productivity across the workforce, but also implied a higher reliance on effort and on a larger share of professionals, both needing to be rewarded with larger wages. The results also show that employee monitoring has reduced over the 2004–2011 period, despite a longer-term increase, starting from 1990s and throughout the 2010s (Gallie et al., 2004), which might also have contributed to the longer-term declining trend in the wage share.

The cross-sectional nature of the dataset requires caution in attributing causation to the relationship between workplace characteristics and wages. While the analysis included the main factors accounting for workplace performance and management practices, some relevant factors driving the association between each independent factor and wage outcomes may have been omitted. Regarding the effect of the share of employees using computers, some unobserved aspects of the technology of production processes may explain both the share of employees using computers and the income level. However, such factors cannot explain the negative association between the share of employees using computers and the wage share, confirming that the opposite effects of computers positive on income level and negative on wage share, are not likely to be a statistical artefact.

Despite those limitations, the analysis has important implications. Its results regarding the labour-augmenting nature of computers and the low levels of substitutability between labour and the other production inputs offer a novel insight into the distributional effect of ICTs. Whilst heterodox economists challenged the hypothesis that ICTs are a key determinant of income inequality (Stockhammer, 2017), the presented results, while not supporting the mainstream interpretation of the distributional role of information technology, support the idea that computers affect the wage share of income. The factors through which computers affected the wage share were – contrary to the mainstream view (IMF, 2007; Karabarbounis and Neiman, 2014; Piketty, 2014) – the least skilled occupations, and included management and organisation practices which demand more attention from the literature on the wage share, such as the workplace's work effort, monitoring, employee involvement and improvement groups.

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Data availability

Additional results and copies of the Stata syntax used to generate the results presented in the paper are available from the author at n.pensiero@soton.ac.uk. Data can be obtained from the UK Data Service at: https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=5294 https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=7226

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Supplemental Material

Supplementary material for this article is available online.

Notes

1. While the definition of capital varies across the studies reviewed, the proposed empirical analysis defines capital as land and all types of equipment.
2. Piketty (2014) argues that the rate of return to monetisable capital and the growth of monetisable capital increase together, which, in a low growth rate scenario, leads to an increase in the rate of return to capital with respect to national income and leads to increasing wealth inequality and dynastic wealth concentration. This narrative is plausible only under the assumption that labour and capital can be substituted for one another and that technology is capital augmenting. If, instead, capital and labour are complements, then the rate of return to monetisable capital grows less fast than the growth of monetisable capital, which is a challenge to Piketty's theory about the innate tendency of capital accumulation (Varoufakis, 2014). To be sure, I agree with Piketty's conclusions about the increasing concentration of capital (and wealth), but his theory is debatable.
3. I follow the standard approach in the literature by not using this measure as a covariate in the wage share model, as it is in the denominator of the outcome variable.
4. The income (output) elasticity of a factor is estimated using a linear combination of the parameters with respect to that factor (Belotti et al., 2013). See Supplementary Appendix B.
5. The income (output) elasticity is calculated using the lincolm programme in Stata 16 as the following linear combination of parameters: $\frac{\partial \ln Y}{\partial \ln C}(s_C) = \beta_C + \beta_{CC}$ mean $\ln C + \beta_{CL}$ mean $\ln L + \beta_{CI}$ mean $\ln I + \beta_{KC}$ mean $\ln K$.
6. The income (output) elasticity is computed as follows: $\frac{\partial \ln Y}{\partial \ln L}(s_L) = \beta_L + \beta_{LL}$ average $\ln L + \beta_{KL}$ average $\ln K + \beta_{CL}$ average $\ln C + \beta_{LI}$ average $\ln L$. The Appendix contains an extended explanation.
7. The income (output) elasticity is computed as follows: $\frac{\partial \ln Y}{\partial \ln L}(s_I) = \beta_I + \beta_{II}$ average $\ln I + \beta_{KI}$ average $\ln K + \beta_{CI}$ average $\ln C + \beta_{LI}$ average $\ln L$. The Supplementary Appendix B contains an extended explanation.
8. By definition the inverse of the share of professional employees and of intermediate employees is, respectively, the share of non-professional and non-intermediate employees. As the model specification includes both variables, the effect of those variables reflects the extent to which the outcome changes when the share of professional (intermediate) employees increases and the

share of least skilled employees (non-professional and non-intermediate employees) decreases, holding the share of intermediate (professional) employees constant.

9. This is inverse of the coefficient for the share of professional employees.
10. This is inverse of the coefficient for the share of intermediate employees.
11. The elasticity of substitution is $\sigma_{AES} = \frac{\beta_{LC}}{s_C * s_L} + 1$, where s_L and s_C are the income (output) elasticity of computers and professional employees (Supplementary Appendix B).
12. The elasticity of substitution is $\sigma_{AES} = \frac{\beta_{IC}}{s_C * s_I} + 1$, where s_C and s_I are the income (output) elasticity of computers and intermediate employees (Supplementary Appendix B).
13. The elasticity of substitution is $\sigma_{AES} = \frac{\beta_{KC}}{s_K * s_I} + 1$, where s_K and s_I are the income (output) elasticity of capital and computers (Supplementary Appendix B).

References

Acemoglu D (2003) Labor- and capital-augmenting technical change. *Journal of the European Economic Association* 1(1): 1–37.

Acemoglu D and Autor D (2011) Skills, tasks and technologies: implications for employment and earnings. In: Ashenfelter O and Card D (eds). *Handbook of Labor Economics*. Amsterdam: Elsevier, Vol. 4, 1043–1171.

Achur J (2010) *Trade Union Membership 2009*. London, UK: Department for Business Innovation and Skills.

Addison JT, Bryson A, Teixeira P, et al. (2013) The extent of collective bargaining and workplace representation: transitions between states and their determinants. a comparative analysis of Germany and Great Britain. *Scottish Journal of Political Economy* 6(2): 182–209.

Adrjan P (2018) *The Mightier, the Stingier: Firms' Market Power, Capital Intensity, and the Labor Share of Income*. Munich: University Library of Munich. MPRA Paper No. 83925. Available at: https://mpra.ub.uni-muenchen.de/83925/1/MPRA_paper_83925.pdf (accessed 2 January 2021).

Allen R (1938) *Mathematical Analysis for Economists*. London: Macmillan and Co Ltd.

Andrews M and Simmons R (1995) Are effort bargaining models consistent with the facts? An assessment of the early 1980s. *Economica* 62(August): 313–334.

Autor D, Dorn D, Katz LF, et al. (2017) *The Fall of the Labor Share and the Rise of Superstar Firms*. NBER Working Paper 23396. Cambridge, MA: National Bureau of Economic Research. Available at: https://www.nber.org/system/files/working_papers/w23396/w23396.pdf (accessed 3 January 2021).

Autor D, Dorn D, Katz LF, et al. (2020) The fall of the labor share and the rise of superstar firms. *The Quarterly Journal of Economics* 135(2): 645–709.

Belotti F, Daidone S, Ilardi G, et al. (2013) Stochastic frontier analysis using Stata. *The Stata Journal* 13(4): 719–758.

Bengtsson E (2014) Do unions redistribute income from capital to labour? Union density and labour's share since 1960. *Industrial Relations Journal* 45(5): 389–408.

Blanchflower DG and Bryson A (2009) Trade union decline and the economics of the workplace. In: Brown W, Bryson A, Forth J, et al. (eds) *The Evolution of the Modern Workplace*. Cambridge: Cambridge University Press, 48–73.

Bowles S and Gintis H (1988) Contested exchange: political economy and modern economic theory. *The American Economic Review* 78(2): 145–150.

Bowles S and Jayadev A (2006) Guard labor. *Journal of Development Economics* 79(2): 328–348.

Bryson A, Forth J and Laroche P (2011) Evolution or revolution? The impact of unions on workplace performance in Britain and France. *European Journal of Industrial Relations* 17(2): 171–187.

Burchell BJ, Day D, Hudson M, et al. (1999) *Job Insecurity and Work Intensification: Flexibility and the Changing Boundaries of Work*. York, UK: Joseph Rowntree Foundation Report.

Chirinko RS (2008) σ: The long and short of it. *Journal of Macroeconomics* 30(2): 671–686.

Christensen LR, Jorgenson DW and Lau LJ (1973) Transcendental logarithmic production frontiers. *The Review of Economics and Statistics* 55(1): 28–45.

David H and Dorn D (2013) The growth of low-skill service jobs and the polarization of the US labor market. *American Economic Review* 103(5): 1553–1597.

Dinlersoz E and Wolf Z (2018) *Automation, Labor Share and Productivity: Plant-Level Evidence from US Manufacturing*. Washington DC: US Census Bureau Center for Economic Studies. Working Paper, 18-39. Available at: https://www2.census.gov/ces/wp/2018/CES-WP-18-39.pdf (accessed 3 January 2021).

Elger T (1990) Technical innovation and work reorganisation in British manufacturing in the 1980s: continuity, intensification or transformation? *Work, Employment and Society* 4(Special IssueMay): 67–102.

European Commission (EC) (2007) The labour income share in the European Union. In: Directorate-General for Employment and Social Affairs and Equal Opportunities (eds) *Employment in Europe*. Brussels: European Commission, 237–272.

Felstead A and Green F (2017) Working longer and harder? A critical assessment of work effort in Britain in comparison to Europe. In: Grimshaw D, Fagan C, Hebson G, et al. (eds) *Making Work More Equal: A New Labour Market Segmentation Approach*. Manchester: Manchester University Press, 182–209.

Gallie D, Felstead A and Green F (2004) Changing patterns of task discretion in Britain. *Work, Employment and Society* 18(2): 243–266.

Gollin D (2002) Getting income shares right. *Journal of Political Economy* 110(2): 458–474.

Gordon R (2005) Where Did the Productivity Growth Go? NBER Working Paper 11842. Cambridge, MA: National Bureau of Economic Research.

Green F (2004) Why has work effort become more intense? *Industrial Relations* 43(4): 709–741.

Green F (2006) *Demanding Work: The Paradox of Job Quality in the Affluent Economy*. Princeton, NY: Princeton University Press.

Green F, Felstead A, Gallie D, et al. (2021) *Working Still Harder*. Industrial and Labor Relations Review.

Green F and Mcintosh S (2001) The intensification of work in Europe. *Labour Economics* 8(2): 291–308.

Gregory T, Salomons A and Zierahn U (2016) *Racing with or against the machine? Evidence from Europe*. ZEW-Centre for European Economic Research Discussion Paper. (16-053).

Greiner A, Rubart J and Semmler W (2004) Economic growth, skill-biased technical change and wage inequality: A model and estimations for the US and Europe. *Journal of Macroeconomics* 26(4): 597–621.

Growiec J (2012) Determinants of the labor share: evidence from a panel of firms. *Eastern European Economics* 50(5): 23–65.

Huber E and Stephens JD (2014) Income inequality and redistribution in post-industrial democracies: demographic, economic and political determinants. *Socio-Economic Review* 12(2): 245–267.

International Monetary Fund (IMF) (2007) The globalization of labor. In: International Monetary Fund. Research Dept. (ed) *World Economic Outlook. April 2007*. Washington, DC: IMF.

Jiang K, Lepak DP, Hu J, et al. (2012) How does human resource management influence organizational outcomes? A meta-analytic investigation of mediating mechanisms. *Academy of Management Journal* 55(6): 1264–1294.

Jiang K and Messersmith J (2018) On the shoulders of giants: a meta-review of strategic human resource management. *The International Journal of Human Resource Management* 29(1): 6–33.

Kanbur R (2000) Income distribution and development. In: Atkinson A and Bourguignon F (eds) *Handbook of Income Distribution*. Amsterdam: Elsevier, Vol. 1, 791–841.

Karabarbounis L and Neiman B (2014) The global decline of the labor share. *The Quarterly Journal of Economics* 129(1): 61–103.

Kristal T (2010) Good times, bad times: postwar labor's share of national income in capitalist democracies. *American Sociological Review* 75(5): 729–763.

Kristal T (2013) The capitalist machine: computerization, workers' power and the decline in labor's share within US industries. *American Sociological Review* 78(3): 361–389.

Lawrence RZ (2015) *Recent Declines in Labor's Share in US Income: A Preliminary Neoclassical Account*. NBER Working Paper 21296. Cambridge MA: National Bureau of Economic Research. Available at: http://www.nber.org/papers/w21296 (accessed 4 January 2021).

Millward N, Forth J and Bryson A (2000) *All Change at Work? British Employee Relations 1980–98 Portrayed by the Workplace Industrial Relations Survey Series*. London, UK: Routledge.

Oberfield E and Raval D (2014) *Micro Data and Macro Technology*. NBER Working Paper 20452. Cambridge, MA: National Bureau of Economic Research. Available at: http://www.nber.org/papers/w20452 (accessed 4 January 2021).

Office for National Statistics (2010) *Standard Occupational Classification 2010 Volume 1: Structure and Descriptions of Unit Groups*. Basingstoke: Palgrave Macmillan.

Patel PC, Messersmith JG and Lepak DP (2013) Walking the tightrope: an assessment of the relationship between high-performance work systems and organizational ambidexterity. *Academy of Management Journal* 56(5): 1420–1442.

Pensiero N (2017) In-house or outsourced public services? A social and economic analysis of the impact of spending policy on the private wage share in OECD countries. *International Journal of Comparative Sociology* 58(4): 333–351.

Pfeiffer S and Kawalec S (2020) Justice expectations in crowd and platform-mediated work. *The Economic and Labour Relations Review* 31(4): 483–501.

Piketty T (2007) Income, wage and wealth inequality in France, 1901-98. In: Atkinson AB and Piketty T (eds) *Top Incomes over the Twentieth Century: A Contrast between Continental European and English-Speaking Countries*. Oxford, UK: Oxford University Press, 43–81.

Piketty T (2014) *Capital in the Twenty-First Century*. Cambridge, MA: Belknap.

Piketty T and Saez E (2007) Income, wage and wealth inequality in the United States, 1913-02. In: Atkinson AB and Piketty T (eds) *Top Incomes over the Twentieth Century: A Contrast between Continental European and English-Speaking Countries*. Oxford, UK: Oxford University Press, 141–225.

Piketty T and Zucman G (2013) Capital is back: wealth-income ratios in rich countries 1700–2010. *Quarterly Journal of Economics* 129(3): 1255–1310.

Reshef A (2013) Is technological change biased towards the unskilled in services? An empirical investigation. *Review of Economic Dynamics* 16(2): 312–331.

Shin D and Konrad AM (2017) Causality between high-performance work systems and organizational performance. *Journal of Management* 43(4): 973–997.

Siegenthaler M and Stucki T (2015) Dividing the pie: firm-level determinants of the labor share. *ILR Review* 68(5): 1157–1194.

Stockhammer E (2009) Determinants of functional income distribution in OECD countries. IMK Studies 5/2009. Available at: https://www.boeckler.de/pdf/p_imk_studies_5_2009.pdf (accessed 5 January 2021).

Stockhammer E (2017) Determinants of the wage share: a panel analysis of advanced and developing economies. *British Journal of Industrial Relations* 55(1): 3–33.

Tomaney J (1990) The reality of workplace flexibility. *Capital and Class* 40: 29–60.

Van Wanrooy B, Bewley H, Bryson A, et al. (2013) *The 2011 Workplace Employment Relations Study: First Findings*. London: Department for Business, Innovation and Skills. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/336651/bis-14-1008-WERS-first-findings-report-fourth-edition-july-2014.pdf (accessed 5 January 2021).

Varoufakis Y (2014) Egalitarianism's latest foe: a critical review of Thomas Piketty's *Capital* in the Twenty-First Century. *Real-World Economics Review* 69: 18–35.

Wei T (2014) *Estimates of Substitution Elasticities and Factor-Augmented Technical Changes*. Oslo (Norway). Center for International Climate and Environmental Research (CICERO).

Young AT (2010) US elasticities of substitution and factor-augmentation at the industry level. Working Paper 10-06. Morgantown, WV: West Virginia University, College of Business and Economics.

Zuleta H and Young AT (2007) Labor's Shares – Aggregate and Industry: Accounting for Both in a Model of Unbalanced Growth With Induced Innovation. Rosario (Argentina): Universidad del Rosario, Documentos de trabajo 003105, Facultad de Economia.

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