Computers and labour relations: an analysis of the wage share in the United Kingdom workplaces

# Abstract

The paper analyses the distributional consequences of information and communication technologies (ICTs) for the United Kingdom’s workplaces’ wage share. It uses the uniquely rich Workplace Employment Relations Survey (WERS) to construct firm level measures of the main production inputs and outputs and analyse the main mechanisms through which ICTs has influenced the wage share between 2004 to 2011. The analysis shows that the share of the employees using computers impacts the wage share in ways that are at odds with the mainstream view which posits that ICTs complement capital, and that labour can be easily replaced by capital. The results show that the share of employees using computers reduces the wage share by disproportionally increasing the productivity of the least skilled employees, which are not proportionally compensated for this increase of productivity. The stability of the wage share over the period of interest is explained by the rise of the workplace’s share of professional employees and by the rise in work effort, whose positive contribution to the wage share was counteracted by the increased share of employees using computers and by the reduction of the share of employees with pay negotiated by unions, which contributed to reduce the wage share.

# Introduction

Since the 1970s the increasing gap between labour productivity and the sluggish wage growth accompanied by the rise of the share of capital, and particularly corporate profits, has led to a decline of the wage share of national income in many Western societies. In the G7 countries starting from 70% in 1970, the wage share of income has declined by an average 2 percentage points per decade (Adrjan 2018). The possible reasons for this decline are the change in the composition and the decline of the level of government spending (Author 2017, Stockhammer 2017, Huber and Stephens, 2014), globalisation (Stockhammer 2009, Kanbur 2000), weakening bargaining power of unions (Bengtsson 2014, Kristal 2013, 2010) and technological change (IMF 2007, EC 2007).

There is controversy regarding the reasons why information and communication technologies (ICTs) might be contributing to increase the divide between the profit and wage share of output. Some **leading economists theorise that ICTs increased the productivity of capital more than that of labour, increasing the quantity of capital relative to the quantity of labour, which in turn caused the labour’s share of income to decline (Piketty 2014; Karabarbounis and Neiman 2014). This mechanism is the result of the capital augmenting (or biased) nature of ICTs in combination with a high substitutability between capital and labour inputs, which leads firms to increase the use of capital relative to labour inputs. A few economists such as Lawrence (2015), Acemoglu (2003), Wei (2014) and Young (2010) argued 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 technological innovations.**

**Most empirical research on economic inequalities including within the heterodox tradition have overlooked the alternative interpretation of the role of ICTs in production processes – that ICTs are labour augmenting and the possibilities of substitution between labour and other production inputs are limited. At present, there is no conclusive evidence on whether ITCs have had a significant impact on the wage share in the 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 (**Stockhammer 2017, IMF 2007)**. Moreover, data limitation prevented extant research on the wage share from analysing the combined effect of ICTs and the more intangible production inputs, i.e. management techniques on the wage share. On the one hand, research in labour economics focuses on management practices when defining workplaces and showed that compared to workplaces in the United Kingdom in the 1990s, workplaces in the 2000s exert greater pressure on employees to expend more effort (Felstead and Green 2017, Green 2006); on the other, there is no study I am aware of which analysed whether management practices mediate the effect of ICTs on income inequality. This paper’s contribution lies in analysing the extent of the impact of ICTs on the wage share and by proposing an analysis of the main mechanisms accounting for the role of ICTs. The proposed analysis uses 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, employees’ involvement, improvement groups, workplace’s work effort) and capital, and controls for union activity, scope of the market, firm’s performance, and industry. This rich dataset is ideal to analyse whether ICTs are labour or capital augmenting, and to explore new mechanisms, i.e. whether the use of ICTs increases the efficiency of management practices in favour of profits or wages.**

**To pursue this research objectives, I use the firm as the unit of analysis. 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 at the firm level. Autor et al. (2017) support this view empirically showing that the wage share has a large element of between-firm variation.** While m**ost analyses were conducted at the country and sector level, this paper contributes to the small but growing stream of research which uses firms as the unit of analysis (Autor et al. 2020, Dinlersoz and Wolf 2018, Autor et al. 2017,** Adrjan 2018, **Siegenthaler and Stucki 2015, Growiec 2012).**

To address the research objective, 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 output level and share and management practices. The richness of information on firms is ideal for an analysis, like the proposed one, focused on differences between firms, yet the sample covers a period of eleven years and cannot be used to make generalisations about long-term trends. The literature review that follows focuses on the main mechanisms that can explain the association between ICTs and income inequalities. I then present the analytical strategy, the dataset the statistical methods, which include the estimation of both a production and distribution function. The analysis will be centred around the estimation of the impact of computers on the output level and wage share and the mechanisms that account for this impact. Finally, I draw the conclusion of the results for the research on the wage share.

# 2.Literature review

## 2.1 Are computers capital or labour augmenting?

The literature uses two main notions to interpret the distributional effect of those factors. The factor bias of ICTs – whether ICTs disproportionally increase the productivity of some factors relative to others, i.e. capital, high skills or low skills occupations, effort etc. – and substitutability between labour inputs and ICTs. There are two ways in which ICTs could reduce the wage share. The first is the bias that ICTs have towards capital inputs, which coupled with the possibility to replace labour inputs with capital, enables employers to shift resources in favour of capital. The second is that ICTs are biased towards labour, yet, because of the complementarity between labour inputs and ICTs, firms cannot increase the relative use of labour without compromising productivity (Schneider 2011 for a review of theories, Acemoglu 2003, Hicks 1932, Robinson 1932). This hypothesis implies that 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 to prevent the production to become inefficient. The result is that the demand for labour does not increase sufficiently to match its enhanced productivity (Lawrence 2015, Oberfield and Ravel 2014). Hence, the computer-enhanced labour productivity leads to a reduction of the compensation of wages as the increases in labour productivity are transferred to capital’s return rather than to wages. It follows that opposite mechanisms can create a pressure to redistribute the output in favour of profits. The only mechanism that could lead to a technology-led rise of the wage share is a combination of labour augmenting processes and a high substitutability between labour and capital.**

**In line with the first hypothesis, some leading economists theorise that ICTs increased the productivity of capital more than that of labour (capital augmenting), increasing the quantity of capital relative to the quantity of labour, which in turn caused the labour share of income to decline (Karabarbounis and Neiman 2014, Piketty 2014).** 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 (Elsby, Hobjin, and Sahin 2013). Piketty and Zucman (2013) linked 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. The capital augmenting hypothesis inspired the IMF World Economic Outlook (2007), which found overall that technological progress is a substantial and larger contributor to the fall in the wage share of income than the changes in labour market policies. Other results point towards a positive effect of technological change on the wage share. The same IMF study (2007) found that technological change has a positive contribution to the wage share in the US and Stockammer (2013) found that technological change contributes positively to the wage share in developing countries and negatively in developed countries. In contrast to the IMF study, Stockammer (2013) confirmed that financialization, not technological change, is the main driver of the decline of the wage share.

The hypothesis of an inverse relationship between capital intensity and the 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 one (labour augmenting technology) and that ICTs, rather than substituting labour, complement it (Wei 2014, Young 2010, Chirinko 2008).

**The analysis will quantify the consequences of the use of computers on the wage share and use a production function to relate the mechanism of distribution to those of production, namely the easy of substitution between computers and other inputs and the bias of computers with respect to the other inputs.**

## 2.2 Computers and occupational groups

The hypothesis that new ICTs augment the productivity of labour is supported by the upward trend of wages of skilled employees, yet it is not clear whether other occupational groups benefited in a similar way from computer technologies. The canonical Skill-biased technological change (SBTC) hypothesis posits that technology is factor-augmenting, complementing either high or low skill workers (Acemoglu and Autor 2011). Following Tinbergen (1974, 1975), the hypothesis has been used to explain the return to skills as a race between technological advances - which tend to increase the demand for skilled labour - and the increase in the supply of skilled labour. The canonical model has been enriched to include the role of the allocation of skills to tasks (David & Dorn 2013, Acemoglu & Autor 2011), which bears two implications. The first is that the link between skills and tasks is flexible, implying that workers with the same skills can perform different set of tasks in response to changes in labour market and technology. The second is that the direction and extent of skill bias of technological change can vary over time and across countries (Acemoglu & Autor 2011).

Enriched by the inclusion of tasks, the model improves its explanatory power. While it can explain the rise of the wage of high skill occupations which perform complex non-codifiable tasks, which computers cannot perform, it also accounts for less intuitive trends according to the canonical model. During the 1980s to 2005 in the US the wage of middle skill occupations performing mainly routine codifiable tasks declined while the wage of occupations at the bottom of the skill distribution, which perform tasks which are not easily displaced by computers and rely on dexterity, interpersonal relationships and physical proximity, such as service and manual occupations, rose (David and Dorn 2013). Reshef (2013) documented that in the US from 1963 to 2005 the average efficiency of less skilled occupations outgrew that of college graduates in the service sector. This was the consequence of a shift in the occupational composition of less skilled workers in the service sector in favour of non-routine task occupations.

**This literature implies that ICTs can have diverse effects on the productivity of and demand for different occupations. Therefore, the overall effect of ICTs on the wage share depends on whether the increase in wages of occupations whose productivity is enhanced by ICTs compensate (or not) for the negative effect of ICTs on the wages of occupations which do not complement ICTs.**

**The empirical analysis will investigate whether computers increase disproportionally the productivity of professional, intermediate and less skilled labour inputs with respect to capital inputs.**

## 2.3 Computers and management practices

In recent decades innovations in the methods of work organisation aiming at improving the efficiency of production processes and fostering individual’s responsibility and flexibility in contributing to the firm’s performance have been diffused across countries along with new information technologies. There is a substantial body of literature showing an association between those management practices on the one hand and employees’ skills and motivation and effective use of human resources on other (Jiang and Messersmith 2018, Shin an Konrad 2017, Patel, Messersmith and Lepak 2013, Jiang et al. 2012). Computers interact with those practices in two ways. First, they make practices such as just-in-time production methods, total quality management and involvement, motivating and disciplining practices more efficient at allocating work schedules and workflows, enabling a closer match between the fluctuating demand of customers and work effort. Second, computers facilitate the capacity of managers to monitor effort and outputs with high precision (see literature cited in Green 2004, Green and Mcintosh 2000, Burchell et al. 1999), eroding the bargaining power of workers, and reducing the need to incentivise workers through above market wages. A key consequence of these two mechanisms is the effort biased nature of ICTs (Green 2004), which implies that computers might raise disproportionally the productivity of high effort workers relative to that of other factors of production. The analysis will assess whether the increase in the output level associated with the combined use of those management practices and computers is achieved by keeping the level of wages constant or increasing the level of wages accordingly.

## 2.4 Other factors

Recent studies on the bargaining relations between capital and labour focused on the role of globalisation in strengthening the position of capital. The idea is that globalisation increases the economic divide between employers and employees by placing domestic workers in competition with workers from abroad and by weakening the influence of domestic political forces on domestic wages and work conditions (Stockhammer 2017, Kanbur 2000). 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 United Kingdom the institutions and practice of collective bargaining eroded over the last four decades. Not only union density declined, the involvement of unions in workplace regulation eroded considerably, not least because employers recognise and bargain with unions on a voluntary basis (Achur 2010, Millward et al. 2000). As a result, firms often set pay without any negotiation with unions, yet, where they do, they choose to bargain at workplace level rather than at a higher or mixed level (Addison et al. 2013, Van Wanrooy et al. 2013). Research shows that the negative effect of unions on profitability in United Kingdom has been declining since the 1980s, yet it is not clear whether the effect is still statistically significant. Blanchflower and Bryson (2009), using WERS 2004, suggest the effect is no longer significant, while Bryson, Forth and Laroche (2011), using the same data, did find a significant effect. Throughout the analysis, I shall 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 the financial resources available.

# 3 Data and modelling strategy

## 3.1 The Workplace Employment Relations Survey

I use data from the 2011 and 2004 Workplace Employment Relations Survey (WERS), a linked employer-employee survey which provides nationally representative data on workplaces in Britain with five or more employees. WERS is a high-quality representative industrial relations surveys which collects rich data on workplace policies, practices and performance. I use three components of the survey: the face-to-face interviews with managers responsible for employment relations on the workplace’s financial performance (Financial Performance Questionnaire (FPQ)) and on labour relations (The Management Questionnaire (MQ)), and the self-completion questionnaire from a sample of up to 25 employees in each workplace (The Survey of Employees Questionnaire (SEQ)).

In the 2011 survey 545 FPQ interviews were carried out successfully, achieving an overall response rate of 28% of the trading sector workplaces included in the Survey of Managers. In WERS 2004 1070 FPQ interviews were successfully completed with a 54% response rate.

The workplace’s output level is from the FPQ and is defined as the workplace income received over the last year from sales of goods and services net of intermediate costs (value of purchases of goods, services and materials). I used the ONS overall price index to adjust for inflation over the 2004-2011 period.

The wage share is defined as the costs for compensating employees relative to the workplace income net of intermediate costs over the last year.

Excluding non-positive values of the wage share and extreme values of the wage share that are at least twice as large as the workplace income, the matching of the SEQ, FPQ and MQ surveys resulted in a sample of workplaces with complete values on all variables of 391 workplaces from the 2004 survey and 303 from the 2011 survey.

The use of information and communication technologies is proxied by the share of employees which use computers (from the MQ).

Labour inputs are defined using the total number of employees in the workplace, the share of professional employees over the total workplace’s workforce and the share of intermediate employees over the total workplace’s workforce. The latter two indicators capture the capacity of the workforce to produce value-added products and services and does not contain measures of employees’ wages, which would be endogenous to the output level and share. The share of professional occupations is defined using the top three occupational category of the SOC 2000 over the total number of employees, and the share of intermediate occupations is defined using the intermediate category. Both variables are derived using the Survey of 25 randomly chosen employees (SEQ), whilst the total number of employees in the workplace is from the Management Questionnaire (MQ). The SEQ achieved a 54% response rate in 2011 and 61% in 2004.

I use the SEQ to derive the average workplace level of effort and monitoring. The level of effort is the workplace average of the employees’ agreement with the statement that the job requires very hard work ranging from strong agreement (5) to strong disagreement (1); and level of monitoring is the workplace’s average of the employees’ summative index of a battery of Likert items capturing the degree of perceived influence on tasks, pace, method and timing of work, all ranging from ‘a lot’ (1) to ‘none’ (4).

The influence of unions is defined by the share of employees with pay negotiated by unions, which is taken from the MQ and captures at the same time whether one or more unions are involved in setting pay and the coverage of pay negotiations. The answer categories vary from 0 (none) to all (6).

Management practices include the adoption of improvement groups (also called quality circles), just-in-time techniques, and employees’ involvement in decisions. Improvement groups and just-in-time techniques are coded as binary variables. The response categories of the variable employees’ involvement in decision are 1(none) to 4 (a lot). All these indicators are from the MQ.

The measure of capital per worker is the sum of the value (in thousands of pounds) of all land and all types of equipment (including software) adjusted for depreciation and divided by the total number of employees (from the FPQ). I used the ONS overall price index to adjust for inflation over the 2004-2011 period.

Other control variables include the industry in which the workplace operates (two-digit SIC), the financial performance and globalisation. The financial performance is defined using the manager’s assessment ranging from 5 (‘A lot better’) to 1 (‘A lot worse’) of the workplace’s performance relative to other workplaces in the same industry. The indicators of globalisation are whether the workplace faces competition from abroad, and the company’s UK market share, which are both taken from the MQ. It should be noted that the distributional effects of operating in a global market depends on whether the competing firms utilise mainly low wage labour, which is usually the case for imports from low-income countries. This is the reason why in research on the effect of trade globalisation on the income distribution of rich countries, the preferred indicator is imports of manufactural goods from low-income countries. In WERS, we do not know whether the firms from abroad with which the firm in question is competing are from a high- or low-income countries. Hence, the available indicator captures the effect of both the competition with firms in low-income countries - which shifts the distribution in favour of capital - and of the competition with firms in high-income countries, which has an uncertain distributional effect. A similar argument applies to the other indicator of globalisation – the company’s UK market share.

In line with common practice in research on firms’ wages and output, I use natural logs of all continuous variables, because coefficients on the natural-log scale are directly interpretable as approximate proportional differences. As capital per worker, the share or employees using computers, the share of professional employees and work effort contains 0s, I add 1 to each of them before the log-transformation. The variables are also normalised to their means to aid interpreting the non-linear effects.

## 3.2 Statistical methods

**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 Ravel 2014). This paper contributes to the literature on the wage share with an analysis of the role of ICTs in both redistributive and production processes.** As a result, I can directly test the hypotheses regarding the mechanisms underlying the distribution processes. If the effects of any given factor on the output level and output share are consistent, it means 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 turns into either the employee or firm’s rent.

The statistical model is a log-log linear regression model 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), Appendix A). 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 the other two factors of production (Appendix A).

Throughout the analysis, I use 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.

# 4 Results

Table B.1 (Appendix) presents the mean and standard deviation of the main variables for the two surveys. In addition, it includes the daily gross wage per employee and the daily output per employee in pounds, adjusting for inflation. Table 1 presents the main results of the regression models of output level and share. 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. The model specification covers the key production inputs discussed so far – labour inputs (total number of employees, proportion of professional employees, proportion of intermediate employees), the level of computerisation (proportion of employees using a computer), capital inputs[[1]](#endnote-1) (capital per employee), and management practices, and the control variables. Tables C.1 and C.2 (Appendix) presents the results of the regression models when the groups of independent variables are added progressively in a stepwise fashion.

The columns 1 and 3 of table 1 present the results of the regression model for the wage share and output level using the complete list of covariates. The column 2 presents the results of regression model for the wage share allowing the level of computerisation to interact with the main production inputs. I will refer to the results included in columns 1 and 2 when presenting the association between the inputs and the wage share. The column 3 presents the basic production function with no interaction terms and 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 output. 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 output, with a 1% increase in computerisation being associated with a 0.7% output increase[[2]](#endnote-2) [[3]](#endnote-3)(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.

[TABLE 1 HERE]

The number of employees does not show a substantial or statistically significant association with the wage share, while it has a positive association with the output level (0.9% increase, p<0.001). The share of professional employees in the workforce shows a positive and significant association with the wage share (0.6%, p<0.1) and a positive and non-significant one with the output level (0.6% output elasticity[[4]](#endnote-4), 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 the output level (0.8% output increase[[5]](#endnote-5), and 0.3% in the regression model), but the estimates are not statistically significant.

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 the 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.

By introducing an interaction between the share of employees using computers and the share of professional and intermediate employees, the results of model 2 show that workplaces with a higher share of professional and intermediate employees compared to less skilled employees, tend to share more with their workforce than workplaces with fewer professional (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 output level. The share of employees using computers increases the output 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[[6]](#endnote-6), p<0.001) and intermediate employees (7% increase [[7]](#endnote-7), p<0.01).

Demanding more effort from employees rewards more the workforce’s wages than profits or the output level. Demanding more effort is 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 output level, although the latter estimate is not significant. The interaction term in model 2 shows that in highly computerised workplaces the relationship between work effort and the wage share become negative (-2% of the wage share, p<0.1). Computers tend to turn work effort into higher profits.

Workplaces which tend to monitor more their employees generate higher levels of outputs (1% increase, 0.05). The coefficient regarding the wage share is negative and noteworthy, but and non-significant. The coefficient regarding monitoring remains non-significant even when the variable is interacted with the level of computerisation.

Union activity is related to a larger wage share. When the share of employees with pay negotiated by unions increases by 1%, the wage share becomes 0.2% points larger (p<0.01). The interaction term between computers and union activity in model 2 shows that highly computerised workplaces especially benefit from union activity (0.5%, 0.05). There is a negative but non-significant association between union activity and the output level.

Involving employees in decisions shows a negative association with the wage share, which is non-significant (-0.1) in model 1 and significant in the model with all the interaction terms (0.2, p<0.1). The interaction term in model 2 shows that computers turn the involvement of employees in decisions into a lower wage share (-0.62, p<0.1). The association of the variable with the output level is small, negative and non-significant. Improvement groups show similar results as those of the employees’ involvement. There is a negative association with the wage share (-0.2, p<0.1) and a positive association with the output 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 the wage share and a negative and significant one with the output level (-0.4, p<0.1). The interaction with computers does not change these results significantly.

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

The financial performance of the workplace has a negative and significant association with the wage share (-0.4 in model 4, p<0.05) and a positive one with the output level (0.7, p<0.05).

In order to investigate the mechanisms that explain the negative effect of computers on the 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 output level suggests 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 benefit less from computers, yet such workplaces share more 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[[8]](#endnote-8) and -11[[9]](#endnote-9)[[10]](#endnote-10)), 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 other ones too.

The elasticity of substitution between the share of employees using computers and capital is negative and small (-2.2)[[11]](#endnote-11), suggesting the existence of complementarity between the two inputs, although to a smaller extent than that between occupations and computers.

The evidence so far presented suggests that the negative impact of the share of employees using computers on the 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 the three main groups of employees and computers. Workplaces would be incentivised to increase the share of the least skilled employees, yet the complementarity between the different groups of occupations and computers prevents this pressure from turning into a higher demand for any group of occupations. As a result, the higher productivity of highly computerised workplaces is transferred to profits mostly. While the value of elasticity between computers, 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 one (labour augmenting technology) and that ICTs, rather than substituting labour, complement it (Wei 2014, Young 2010, Chirinko 2008). 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 (ad reduce the wage share). Conversely unions are more effective at increasing the wage share in more computerised workplaces.

The cross-sectional nature of the dataset imposes caution in interpreting the “effects” of workplace characteristics on wages as causal relationships. While the analysis included the main factors that account for workplace performance and management practices, I cannot exclude that some unobserved aspects of the technology of production processes explain both the share of employees using computers and the output level.

[FIGURE 1 HERE]

In order to assess the extent to which the different factors have contributed to the stability of the wage share over the period, I construct a measure of each factor’s contribution by multiplying its effect size by its actual change over the period of interest (Figure 1). The effect estimates are taken from model 2. The increase of share of employees using computers contributed substantially to the decline of the wage share (extent of change(0.04)\*effect size(-0.5=-0.02). The level of computerisation has heterogenous effects depending on the factor it interacts with. The share of employees with pay negotiated by unions declined over time, which explains the negative contribution of both the main effect of union activity (extent of change(-0.03)\*effect size(0.2)=-0.02) and the interaction term to the change in the wage share (extent of change(-0.04)\*effect size(0.5)=-0.005). The share of intermediate employees declined too, leading to the same negative contribution to the change of the wage share of the interaction between computers and the share of intermediate employees (extent of change(-0.005)\*effect size(3.1)=-0.015). The negative contributions are balanced by the positive contribution of work effort (extent of change(0.05)\*effect size(0.9)=0.05), which intensified over the period, and the share of professional employees, which also increased over time (extent of change(0.08)\*effect size(0.6)=0.05). The interaction between computers and work effort contributed to increase the wage share (extent of change(-0.002)\*effect size(-2.2)=0.006) as did the one between computers and the share of professional employees (extent of change(0.001)\*effect size(4)=0.04). Improvements groups, which become more prevalent over time, contributed to reduce the wage share both when considering the main effect (extent of change(0.06)\*effect size(-0.18)=-0.01) and the interaction with computers (extent of change(0.01)\*effect size(-1)=-0.01). Finally, the employees’ involvement in decisions, declined over time, leading to a positive contribution to the wage share (extent of change(-0.02)\*effect size(-0.17)=0.003). The interaction between computers and employees’ involvement in decisions had a positive contribution to the wage share (extent of change(-0.003)\*effect size(-0.6)=0.002).

# 5 Conclusions

The article used a firm level dataset to analyse whether computers contribute to reduce the wage share and to assess the reasons for this effect. The regression analyses confirm a positive relationship between the share of employees using computers and the output level and a negative relationship with the wage share. Computers make workplaces more successful at increasing the output 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 computers’ capacity to make other factors more productive is biased towards capital and professional employees (Karabarbounis and Neiman 2014, Piketty 2014, IMF 2007), this analysis suggested that the share of employees using computers increase disproportionally the productivity of the less skilled occupations relative to other factors of production. The results showed that there is complementarity between the share of employees using computers and the least skilled employees. This complementarity in the technology of production processes prevents the computer-enhanced productivity from translating into a higher demand for labour inputs. The result is that the computers-enhanced productivity mostly increases profits.

The inclusion of management practices as production inputs shed light on aspects of the wage share which were never analysed before to the best of my knowledge. The intensity of effort, which is an aspect of the relationship between employees and the employer which are difficult to define in the job contract (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 with a larger wage share their employees. A possible reason is that the workplaces that require employees to expend more effort are more dependent on incentives, including higher wages.

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

In addition, computers show to interact positively with wok effort and some of the management techniques analysed, such as employees’ involvement and improvement groups, but not with monitoring. Highly computerised workplaces tend to turn those practices which rely on the participation of employees to 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 is compensated by the increased share of professional employees and the increased requirement to expend effort. The transformation of production processes has had diverse effects on the wage share. Those transformations increased productivity through the use of computers across the workforce, but have also implied a higher reliance on effort and on a larger share of professionals, both of which need to be rewarded with larger wages. The results also show that monitoring has reduced over the 2004-2011 period. However, in the longer term, starting from 1990s and throughout the 2010s, there has been an increase in monitoring (Gallie et al. 2004), which might also have contributed to the declining trend of the wage share in the longer term.

The results have 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 show a heterodox interpretation of the role of ICTs. The factors with which ICTs interact with to affect the wage share are the least skilled occupations, which challenges the mainstream view of ICTs (Karabarbounis and Neiman 2014, Piketty 2014, IMF 2007), and include management and organisation practices, which deserves more attention than the literature on the wage share is currently giving, such as the workplace’s work effort, monitoring, employees’ involvement and improvement groups.

# Declaration of conflicting interests

The author declared no potential conﬂicts of interest with respect to the research, author- ship and/or publication of this article.

# Funding

This work was supported by the ESRC [grant number ES/J019135/1].

# References

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

Addison, J. T., Bryson, A., Teixeira, P., Pahnke, A. and Bellmann, L. (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*, 60: 182-209.

Autor, D., Dorn, D., Katz, L. F., Patterson, C., & Van Reenen, J. (2020). The fall of the labor share and the rise of superstar firms. *The Quarterly Journal of Economics*, 135(2), 645-709.

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

Adrjan, P. (2018)*. The mightier, the stingier: Firms’ market power, capital intensity, and the labor share of income.* MPRA Paper No. 83925.

Allen, R (1938). Mathematical Analysis for Economists; London; Macmillian & Co Ltd.

Autor, D., Dorn, D., Katz, L. F., Patterson, C., & Van Reenen, J. (2017). *The fall of the labor share and the rise of superstar firms*. National Bureau of Economic Research.

Belotti, F., Daidone, S., Ilardi, G., & Atella, V. (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, D.G. and Bryson, A. (2009). *Trade union decline and the economics of the work­place*. In: Brown W, Bryson A, Forth J and Whitfield K (eds) *The Evolution of the Modern Workplace*. Cambridge: Cambridge University Press, 48–73.

Bowles, S., & Gintis, H. (1988).Contested exchange: political economy and modern economic theory. *The American economic review, 78(2), 145-150.*

Bowles, S., & Jayadev, A. (2006). Guard labor. *Journal of Development Economics, 79(2), 328-348.*

Bryson, A., Forth, J., & 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, B.J., D. Day, M. Hudson, D. Ladipo, R. Mankelow, J. Nolan, H. Reed, I. C. Wichert, and F. Wilkinson (1999) *Job Insecurity and Work Intensification: Flexibility and the Changing Boundaries of Work*. Joseph Rowntree Foundation Report, York, England.

Chirinko, R. S. (2008). σ: The long and short of it. *Journal of Macroeconomics*, 30(2), 671-686.

Christensen, L. R., Jorgenson, D. W., & Lau, L. J. (1973). Transcendental logarithmic production frontiers. *The review of economics and statistics*, 28-45.

Dinlersoz, E., & Wolf, Z. (2018). *Automation, Labor Share, and Productivity: Plant-Level Evidence from US Manufacturing*. US Census Bureau Center for Economic Studies Working Paper, 18-39.

European Commission (EC) (2007). *The labour income share in the European Union. In Employment in Europe*. Brussels: European Commission, pp. 237–72.

Elsby, M. W., Hobijn, B., & Şahin, A. (2013). *The decline of the US labor share*. Brookings Papers on Economic Activity, 2013(2), 1-63.

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

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

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

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

Felstead, A., Gallie, D., Green, F. and Inanc, H. (2013), *Skills at Work in Britain: First Findings from the Skills and Employment Survey 2012* (London: Centre for Learning and Life Chances in Knowledge Economies and Societies: Institute of Education).

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 and Tavora, I (eds) *Making Work More Equal: A New Labour Market Segmentation Approach*, Manchester: Manchester University Press.

Hicks, J. (1932). *The theory of wages*. London: MacMillan.

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

IMF (2007). *The globalization of labor*. In World Economic Outlook, April 2007. Washington, DC: IMF.

Jiang, K., & 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.

Jiang, K., Lepak, D. P., Hu, J., & Baer, J. C. (2012). How does human resource management influence organizational outcomes? A meta-analytic investigation of mediating mechanisms*. Academy of management Journal, 55(6), 1264-1294.*

Kanbur, R., (2000). Income distribution and development. In: Atkinson A and Bourguignon F (eds) *Handbook of Income Distribution*, vol. 1, Ch 13. Amsterdam: Elsevier, pp. 791–841.

Karabarbounis, L., & Neiman, B. (2014). The global decline of the labor share. *The Quarterly Journal of Economics*, 129(1), 61-103.

Katz, L. (1999). *Technological Change, Computerization, and the Wage Structure.* Unpublished manuscript. Cambridge, MA: Harvard University, Department of Economics, 1999.

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.

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

Lawrence, R. Z. (2015). *Recent Declines in Labor's share in US Income: a preliminary neoclassical account* (No. w21296). National Bureau of Economic Research.

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: Routledge.

Oberfield, E., and D., Raval. (2014). *Micro Data and Macro Technology*. NBER Working Paper 20452. Cambridge, MA: National Bureau of Economic Research.

Patel, P. C., Messersmith, J. G., & Lepak, D. P. (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.

Author (2017)

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

Piketty, T. and G. Zucman. (2013). Capital Is Back: Wealth-Income Ratios in Rich Countries 1700–2010. *Quarterly Journal of Economics*, 129 (3), 1255–310.

Piketty, T., (2007). *Income, wage and wealth inequality in France, 1901-98*, in A B Atkinson and T Piketty (eds), *Top incomes over the Twentieth Century*, Oxford University Press, Oxford.

Piketty, T. & Saez, E., (2007). *Income, wage and wealth inequality in the United States, 1913-02*, in A B Atkinson and T Piketty editors, *Top incomes over the Twentieth Century*, Oxford University Press, Oxford.

Robinson, J. (1932). *Economics of Imperfect Competition*. London: MacMillan.

Schneider, D. 2011. *The Labor Share: A Review of Theory and Evidence*. SFB 649 Discussion Paper 2011-069, Humboldt-Universitat zu Berlin.

Shin, D., & Konrad, A. M. (2017). Causality between high-performance work systems and organizational performance. *Journal of Management*, 43(4), 973-997.

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

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.*

Stockhammer, E. (2009). *Determinants of functional income distribution in OECD countries* (No. 5/2009). IMK Study.

Van Wanrooy, B., Bewley, H., Bryson, A., Forth, J. A., Freeth, S., Stokes, L., & Wood, S. (2013). *The 2011 workplace employment relations study: First findings*. Economic and Social Research Council.

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

Young, A.T. (2010). *US Elasticities of Substitution and Factor-Augmentation at the Industry Level*. Working Paper, College of Business and Economics, West Virginia University.

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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | | | |
|  | Wage share (log) | | Output 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 |
| 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 |
| Share of employees using computer^2 (log) |  |  |  | 4.04~ |
|  |  |  |  | 2.24 |
| Capital per employee^2 (log) |  |  |  | 0.05\*\*\* |
|  |  |  |  | 0.01 |
| Share of professional employees^2 (log) |  |  |  | 5.90\*\* |
|  |  |  |  | 2.21 |
| Share of intermediate employees^2 (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 |
| ~ 0.10 \* 0.05 \*\* 0.01 \*\*\* 0.001 |  |  |  |  |
| Other control variable: industry category |  |  |  |  |
| Output level and capital per employee are measured in thousands of pounds | | |  |  |

**Figure 1 - Factors' contribution to the change of wage share, 2004-2011**

# Author details

Nicola Pensiero is a lecturer at Southampton University with a keen interest in social stratification and inequality, and public policy evaluation. He conducted research in the areas of income inequality, educational opportunities in UK and across countries, and education policy evaluation.

1. 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. [↑](#endnote-ref-1)
2. The output elasticity of a factor is estimated using a linear combination of the parameters with respect to that factor (Belotti et al. 2013). See Appendix A. [↑](#endnote-ref-2)
3. Output elasticity is calculated using the lincolm programme in Stata 16 as the following linear combination of parameters: + [↑](#endnote-ref-3)
4. The output elasticity is computed as follows: ++. The Appendix contains an extended explanation. [↑](#endnote-ref-4)
5. The output elasticity is computed as follows: +. The Appendix contains an extended explanation. [↑](#endnote-ref-5)
6. This is inverse of the coefficient for the share of professional employees. [↑](#endnote-ref-6)
7. This is inverse of the coefficient for the share of intermediate employees. [↑](#endnote-ref-7)
8. The elasticity of substation is , where and are the output elasticity of computers and professional employees (Appendix). [↑](#endnote-ref-8)
9. [↑](#endnote-ref-9)
10. The elasticity of substation is . where and are the output elasticity of computers and intermediate employees (Appendix). [↑](#endnote-ref-10)
11. The elasticity of substation is . where and are the output elasticity of capital and computers (Appendix). [↑](#endnote-ref-11)