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Harminder Battu
Clive R. Belfield
Peter J. Sloane

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Harminder Battu
Department of Economics, University of Aberdeen

Clive R. Belfield
National Center for the Study of Privatization in Education, Teachers College, Columbia University

Peter J. Sloane
Department of Economics, University of Aberdeen and IZA, Bonn

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IZA

P.O. Box 7240
D-53072 Bonn
Germany

Tel.: +49-228-3894-0
Fax: +49-228-3894-210
Email: iza@iza.org

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ABSTRACT

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An individual's human capital has a strong influence on earnings. Yet individual, worker-level estimations of earnings rarely include the characteristics of co-workers or detailed firm-level controls. In this paper, we use a unique matched worker–workplace dataset to estimate the effect on own earnings of co-workers' education. Our results, using the 1998 UK Workplace Employee Relations Survey, show significant effects. Own earnings premia fall slightly, but there is an independent, significantly positive effect from average workplace education. We also test for interactions between own and co-worker education levels. However, these interactions appear negative: education is valued less highly at workplaces where education levels are already high. This result runs counter to our theoretical prediction.

JEL Classification: I2, J4

Keywords: Educational economics, human capital, workplace performance

Peter J. Sloane
Department of Economics
University of Aberdeen
AB24 3QY
Scotland
Tel.: +44 (0)1224 272080
Fax: +44 (0)1224 272082
Email: pec063@abdn.ac.uk

1. Introduction

The education earnings relationship is one of the most intensively tested in economics (Lazear, 2000) and there is substantial evidence that an individual workers' productivity and wages depend in large part on their human capital. There is also a sizeable literature on social externalities from education, i.e. spillover benefits from educated individuals to others (Wolfe and Zuvekas, 2000). However, there is surprisingly little evidence on whether these spillover effects obtain within the workplace, and what effect these might have on own earnings. In particular, there is no clear indication as to whether educated co-workers raise or lower own earnings.

There are a number of potential avenues through which co-workers' human capital will influence own wages: Idson and Kahane (2000) refer to a team dynamic, but equally strong effects may emerge from information-sharing, from skill complementarity and from training by co-workers (Barron et al., 1997), or from more 'rational' behaviour (Behrman and Stacey, 1997). It seems likely that co-workers will trade these human capital skills, to mutually raise productivity. However, there are two potential reasons as to why co-workers' human capital need not be complementary to own human capital. First, if co-workers have different amounts of human capital, then there may be a 'skills incompatibility' (Kremer, 1993): a firm with a uniform standard of education may have higher productivity. Second, if workers are in competition with each other for high-paying jobs within the firm, they may engage in activities to undermine their competitors and promote themselves

(Winter-Ebmer and Zweimuller, 1997). [1] Thus, both the amounts and the distribution of workplace human capital are likely to influence earnings, and the directions of these influences can only be assessed empirically.

This paper tests these human capital interactions directly, using random samples of workers from UK workplaces. The paper is structured as follows. In Section 2, the possible externalities from co-worker human capital are discussed, along with the pertinent (but mainly indirect) evidence; this discussion allows for formulation of testable hypotheses about the effects on earnings. In Section 3 we describe the dataset used: the UK Workplace Employee Relations Survey (1998). In Section 4, the effects of workplace education on own earnings are tested. In Section 5, a summary and conclusion is offered.

2. Theory and Evidence on Human Capital Spillovers

2.1 Returns to Human Capital Within the Workplace

The literature on the earnings premia from education is vast (see recent reviews by Ashenfelter et al., 2000; Ashenfelter and Rouse, 2000; Cohn and Addison, 2000). Broadly, this cross-sectional, correlational literature indicates that in Western economies the wage premium for each additional year of education is approximately 5–10% (for the UK, see Blundell et al., 2000). Moreover, this premium is not substantially altered when the endogenous decision to become educated is modelled (e.g., from twins studies or natural experiments, Miller et al., 1997; Harmon and Walker, 1995). The impact of own education

[1] Negative effects may also arise if a sizeable proportion of the workforce has more education than is required for their job: they are over-educated (Oosterbeek, 2000). It is well documented that overeducation generates a wage penalty relative to being fully matched.

on own productivity and earnings is strong and robust. In addition, workers' productivity may also depend on the education of co-workers within the firm. Workers do not always work autonomously. Many tasks require group work, with skills diffused through teams and across the workplace; and organisational cultures (e.g. those associated with high-performance management) may depend on the average workforce skill level. Furthermore, firms may deliberately cultivate a team dynamic, with information-sharing, co-training, monitoring, and support so as to exploit these spillovers. Idson (1995), for example, looks at how earnings are correlated with production in teams, as well as with behavioural traits such as team size, encouragement and helpfulness.

The notion of human capital spillovers gains support from the substantial literature on the societal externalities from education (Wolfe and Zuvekas, 2000; Taylor, 2000). In fact, enterprises may even be able to generate more externalities than exist in societies, insofar as they can enforce tighter contracts across workers. The possibility of positive spillovers is at least indirectly suggested by evidence such as the positive clustering of high-skilled professionals with high-skilled non-professionals in the US (Bronars and Famulari, 1997), the positive earnings effect from increasing proportions of skilled workers in a firm (Troske, 1999), and from sports performances, where team dynamics clearly occur (Idson and Kahane, 2000).[2] As well, there is a positive correlation between all individuals' earnings and the average education level of a region (Rauch, 1993), and a 'brain drain' of educated workers to areas where there are other educated workers (Borjas et al., 1992).[3] Human

[2] Macro-economic models and endogenous growth models draw on the notion of 'production externalities', with economic growth boosted through more efficient social capital investments (McMahon, 2000; Romer, 1994).

[3] In an unpublished study, Barth (2000) directly tests the effects on co-worker earnings using two types of matched employer–employee data from Norway: an independent effect on own pay from the average level of education within an establishment ranges from 1% to 4% per year of average education. In

capital spillover effects may therefore exist: working with others who have high education levels may independently raise own earnings (and this may explain some of the observed firm-level heterogeneity in earnings, see Bayard and Troske, 1999; Abowd et al., 1999).

However, own earnings may be affected by the dispersion of human capital within the workplace. This line of argument may run counter to the notion of externalities. In Kremer's (1993) o-ring theory, for example, the productivity of high-skilled workers is increasing in the skill levels of co-workers. The o-ring theory predicts that an important determinant of factor payments is the compatibility of standards: where workers are of a 'compatible standard', they will earn more. Perhaps training programs are easier to implement (Barron et al., 1997; van Smoorenberg and van der Velden, 2000), or there are fewer co-ordination failures in standardised workplaces. In this theory, an increase in education levels within the workplace may not raise earnings if it also serves to widen the dispersion of education levels; but earnings will be raised where high-skilled workers cluster together.

More generally, there is a sizeable literature that indicates that many workers do not have the optimal amount of education for their jobs (see the review in Oosterbeek, 2000). For the UK, over-education is significant and substantive, years of surplus education only weakly affect individual earnings, and they negatively affect job satisfaction (Battu et al., 1999; Dolton and Vignoles, 2000). The point is that if workers have accumulated more education than is optimal, any externalities may be subverted: for an individual worker, over-education may mean reduced productivity, earnings and job satisfaction, while at the same

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contrast, Groshen (1991) finds that education levels very weakly reduce establishment wage time that worker may distract or demoralise other workers. Monitoring costs for the firm may be pushed up, to avoid workers who adroitly perform the set tasks distracting co-workers.[4] So although co-workers' years of education may boost earnings, if these are surplus years of education they may impair own earnings.[5]

A third reason to doubt a positive effect from co-worker human capital is the possibility of intra-firm job tournaments. Where workers with equivalent skills compete for promotions, they may sabotage each other, and so reduce productivity overall. Finally, spillover effects may not be appropriated by workers, but instead by managers in terms of higher profits. Although possible, this last effect seems unlikely since highly educated workers would probably be the most effective at bargaining for higher shares of the workplace surplus.

There are plausible arguments on both sides, regarding the complementarity of human capital within a workplace. Ultimately, the net effect can only be decided empirically. In addition, such empirical research may have implications for assessing the benefits of education. If human capital spillover effects are important, and there is clustering of education levels within workplaces, this may influence how the earnings premium to education is interpreted. The earnings premium is typically attributed to human capital and not to labor market sorting, i.e. where workers are hired according to their credentials (see the discussion by Belfield, 2000). Yet, part of this premium may be a consequence of

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differentials.

[4] Yet, across the workplace, over-education may be minimal: either the employee mix could be adjusted so that over-educated and under-educated workers compensate for each other, or physical capital intensities may be varied. However, over-educated workers may guide or assist co-workers who only have the required education and it may be under-educated workers who are less competent, need greater monitoring or require more co-worker support (Tsang et al., 1993).

[5] Tsang (1987), with data from the Bell Company, finds over-education reduces firm output via a negative effect on job satisfaction. Other indirect evidence of the effect of the human capital mix on firm

educated workers being hired to workplaces where the average education level is high. These workers then 'share' their human capital and so have higher earnings. Education still enhances productivity and so earnings, but part of that enhancement comes from education's role in securing for a given worker a job which allows for interaction with other skilled workers.

2.2 *Model Specification*

The above arguments can be modelled formally. An appropriate specification of the relationship between own earnings and co-worker attributes is laid out by Idson and Kahane (2000):

$$\ln y_{ij} = a_1 + a_2 e_{ij} + a_3 E_j + a_4 e_{ij} * E_j + a_5 \mathbf{z}_{ij} + a_6 \mathbf{Z}_j + v_j + u_i \quad (1)$$

In equation (1), own individual earnings y_{ij} are determined by: the education e_{ij} of individual i at workplace j; the education levels of co-workers E_j; and the interaction between these two education levels. A vector of worker and workplace controls $\mathbf{z}_{ij}$ and $\mathbf{Z}_j$ are also included (v_j~N(0, σ_j) and u_i~N(0, σ_i) are iid workplace and individual error terms). Under this specification, an additional year of an individual worker's own education affects their earnings by $a_2 + a_4 E_j$. The coefficient a_2 captures the direct effect of years of education, and the coefficient a_4 captures the effect of average co-worker education on how own education is valued. An additional cross-workplace increase in education of one year will increase own earnings by $a_3 + a_4 e_{ij}$. Co-worker education will impact directly through the coefficient estimated as a_3, and indirectly through the interaction coefficient a_4. Here, if a_3 is

performance includes the negative effect of proportions of unskilled or manual workers (Machin and non-zero, then its omission (or that of a_4) serves to bias upwards a_2, the standard measure of the education premium. The expectation is that a_3 and a_4 will be positive, although only limited evidence is so far available on each of these coefficients. Where a_3 is positive, own earnings are positively related to co-workers' education; where a_4 is positive, increased years of co-worker education raise wages for those with high education levels.

The sign of coefficient a_4 offers one test of Kremer's hypothesis about compatible standards of inputs, but further tests are also possible. One simple test is to include the absolute mean dispersion of education levels $\acute{E}_j$ on the right hand side of equation (1). To capture non linear effects we can also include the square of workplace human capital E_j^2. Both these tests are included below.

In summary, the following hypotheses are offered. First, own education raises earnings. Second, workplace education levels raise own earnings. Third, the dispersion of workplace education levels lowers earnings. It is possible to test these hypotheses using matched worker-workplace data.

3. Data and Measures

To test these hypotheses, the dataset used is the Workplace Employee Relations Survey (WERS), collected in 1998 (DTI, 1999). The WERS is a national sample of interviews with managers from 2,191 UK establishments with at least ten workers. The firm-level survey addresses the 'management of employees', with information on workforce

Stewart, 1996; McNabb and Whitfield, 1998; Addison and Belfield, 2000).

composition and workplace performance (see Cully et al., 2000). In addtion, 25 employees at each workplace were randomly selected for individual survey. This survey asked questions about individuals' education, pay and job satisfaction, as well as a range of personal characteristics. The information set is therefore rich, with detailed information on multiple workers per workplaces. For estimation, the sample here is restricted to full-time workers and to workplaces where more than three workers responded to the worker survey. This yields information on 18,304 workers across 1,389 workplaces.

The derivation of the key variables is briefly described here: a full derivation is reported in Appendix Table 1, along with a catalogue of substitute derivations of the key variables. The simplest way to estimate these relationships is to use years of education as the unit of account. First, each workers' years of education were calculated, to obtain e_i; these calculations were based on qualifications, and so full sensitivity analysis is conducted below. Second, workplace education levels E_j were derived using both worker and workplace data. Based on the full worker sample, mean years of education per occupation are calculated. This mean can then be weighted for each workplace, using information on the occupational mix of the entire workforce at each workplace. (Two alternative measures of mean workplace education are available, and these are utilized in the sensitivity testing). Third, the dispersion of workplace education levels $\acute{E}_j$ is also calculated: this dispersion measure is the average of absolute differences between own education and mean workplace education. Fourth, pay levels y_{ij} are taken from self-reports across 12 wage bands, and converted into earnings per hour using the reports of hours worked. Median pay across the workplace Y_j is also available; this variable is based on the distribution of pay across the workforce, as reported by the manager.

Basic frequencies for the key variables are reported in Table 1 (with full frequencies for the other variables detailed in Appendix Table 2). The average years of education per male (female) worker are 13.67 (13.76). Mean education levels per workplace are 13.45 (s.d., 1.20), so the sample of respondents has slightly more education than the average of their workplace. The dispersion of education across a workplace is 2.21 (s.d., 0.64). For the dependent variables, log pay per hour per individual worker is 1.94; and log median earnings per workplace are 9.55.

Such matched worker–workplace data is ideal for testing the hypotheses listed above. There are detailed controls for each worker, workplace information from two sources (the manager and the worker respondents), and full information on education, pay, and job satisfaction. This allows for numerous sensitivity tests and cross-validation of the results. One potential caveat is that this analysis relates to workplaces rather than teams: co-worker, in this sense, refers to those in the same workplace, rather than those doing the same tasks or team-working. (No ability controls are available, either). Nevertheless, the random sample of workers and the detailed information on both workers and workplaces – essential for investigating these arguments – is unique for the UK economy.

4. Estimation and Results

4.1 The Effects of Workplace Education on Own Earnings

The main hypothesis is whether earnings are increasing in the education levels of co-workers. Table 2 reports a series of Mincerian earnings equations, estimated with both own and co-worker levels of education against log pay per hour. As per equation (1), which includes error terms for workplaces and individuals, Random Effects Generalized Least Squares is used.[6] Model [1] includes individual characteristics $\boldsymbol{z}_i$ only (detailed in the notes to Table 2); it shows the earnings premium for an additional year of education is 6.0% (6.4%) for males (females). Approximately 40% of the variation in earnings is explained; and the fraction of the variance attributable to the workplace error term $?_j$ is 0.3710 (0.3496). By introducing firm-level characteristics $\boldsymbol{Z}$ as per Model [2], the premium to education falls slightly, with an increase in the explained variation to 47% (46%); and the workplace error term variance falls, so $?_j$ is now 0.2833 (0.2437).

Model [3] includes the average years of education across the workplace E_j as an additional firm-level variable. This variable is statistically significant and has a substantive effect on own earnings: an across-the-workplace increase in education of 1.2 years (one standard deviation) raises own earnings by 13.0% (8.9%). The premium to own education is reduced, although again not substantially. The strength of the coefficient (a_3>0) suggests that own and co-worker education appear to be strongly complementary. In substantive terms, it is important to note that an increase of one standard deviation must be applied across all the workforce, and the average workforce size is 45. Based on the premium to education, for an enterprise which raises workplace education levels by one standard deviation then the total wage bill would be approximately 7% higher.

Model [4] is the full estimation specified as equation (1), to include the interaction between own and co-worker years of education (Idson and Kahane, 2000). This

[6] Random effects GLS is a less biased estimator than OLS, because the data are grouped across workplaces (Moulton, 1987). A Hausman test easily rejects the use of OLS ($?^2$=99.88). Using OLS, the coefficient on e_{ij} for Model [1] is 0.0785 (0.0732) for males (females).

interaction term has a negative sign for males and is statistically significant at 1% level (no effect is identifiable for females). Own education appears to be rewarded at a relatively *lower* rate in firms where education levels are already high. This result (a_4<0) runs directly counter to the predictions of Idson and Kahane (2000) and Kremer (1993). However, these relationships can be tested further.

The effect of the spread of human capital is reported in Table 3. Two tests are applied. First, a direct measure of dispersion $\acute{E}_j$ is included in Model [4] in place of the interaction term. The upper panel of Table 3 shows that, adjusting for overall workforce human capital, greater dispersion of education across the workplace is associated with higher own earnings: a one standard deviation increase in dispersion raises own earnings by 2.3% (3.3%). Second, the square of workplace years of education is reported in the bottom panel of Table 3. The coefficients on workplace education are positive, but for its square they are negative: workplace education boosts own earnings, but at a declining rate. Both these tests suggest against the hypothesis of increasing returns to skill in standardised workplaces.

Finally here, the effects are tested across union and non-union workers. This split is interesting, because the results could go either way. Unions may facilitate the sharing of skills across workers, who then collectively bargain over pay. With facilitation, the probability of invidious competition between workers would be lower and so cross-workplace spillovers of human capital should be stronger. Yet, if unions instead demarcate skills and apportion tasks, this would reduce the opportunities for human capital spillovers. Models [3] and [4] are reported in Table 4. These estimations show that both the returns to own education and to co-worker education are lower amongst union members. Moreover, the interaction term $e_{ij}*E_j$ is strongly significant and negative for male non-union workers, but not for union workers (yet, for female non-union workers it is positive; for union workers it is negative). These results suggest that unions – by reducing the returns to education – play a demarcational role, rather than a skill-sharing one.

4.2 The Effects of Workplace Education on Own Earnings: Sensitivity Tests

A series of tests for the robustness of the results in Table 2 were undertaken. The sensitivity tests were grouped in three categories: (i) restrictions on the sample for estimation; (ii) respecification of the data; and (iii) use of alternative derivations of e_i, E_j and y_{ij}.

Table 5 reports estimations of Models [3] and [4], but with sample restrictions applied. The sample is restricted to those workplaces where it might plausibly be expected that human capital spillovers would be the strongest, i.e. those workplaces where there is high team-working and or where the technology is labor-intensive.[7] Reducing the sample inflates the standard errors, and this generates some sensitivity across the results. First, the sample is restricted to firms where at least 60% of workers are reported to work in teams, on the assumption that human capital spillovers will be strongest in workplaces where team-working is prevalent. Panel 1 of Table 5 shows that the coefficient for E_j remains statistically significant, as does the interaction term e_i*E_j for male workers. Second, the sample is only of workers in labor intensive firms, i.e. where labor accounts for more than 75% of operating costs. In panel 2 of Table 5, average years of education remain significant, but here the interaction term falls to insignificance.

[7] Small firms may also rely more on human capital spillovers. When only firms of less than 40 workers are included, however, the interaction terms are all insignificant.

As a second set of checks, a series of further specification tests were undertaken. These tests included: OLS estimation for each specification; inclusion of occupational dummy variables for each individual; pooling the genders; and application of the survey weights for the data. In most cases, the results were unaffected; in some cases, the negative effect was strengthened and in only instance (male union sample, occupational dummies included) was a positive and statistically significant coefficient obtained for the interaction term e_i*E_j.

The third set of sensitivity tests related to alternative derivations of the key dependent and independent variables e_i, E_j and y_{ij}. First, workplace education levels E_j were re-calculated using occupational averages from the 1998 UK Labour Force Survey and using the actual average of the workers' responses. These are described as $E2_j$ and $E3_j$ in the Appendix. Second, the dispersion measure was calculated using squared dispersions rather than absolute dispersions (see Appendix Table 1). Finally, interval regression was applied to the log of annual earnings values $y2_{ij}$, instead of log pay per hour y_{ij}.[8] Across this set of tests, the coefficients represented in Tables 2–5 were unaffected.

4.3 The Effects of Workplace Education on Median Workplace Wages

A final relevant estimation is available using the WERS. This draws on the workplace level reports of the log median wage across each firm Y_j (see the Appendix for calculation). As with earlier estimations of Model [3], column 1 of Table 6 shows the strongly positive effect of the average education level on the median wage of the establishment. Increasing the

[8] The interval regression yielded no differences in the results, compared to those reported in the main text. Hourly pay is used here, as a better measure of productivity, than the annual pay intervals. Hourly pay is not fully in intervals, because individuals reported the exact number of hours worked; so interval

average workforce education by 1.2 years, this raises the median workplace wage by 15.6%, similar to the estimate of 13.0–8.9% reported in Table 2, given that the latter controls directly for own education. Column 2 shows the effect of the dispersion of education: a one standard deviation increase in dispersion raises median earnings by 1.4%. Again, these results are not sensitive to the weighting procedure or more parsimonious modelling.

5. Conclusion

For the first time using British data this paper investigates the possibility that there are spillover effects of education within the workplace. Spillover effects are found to positively influence own earnings, and these effects are largely independent of the effect from own education. However, the hypothesis that co-worker education is most beneficial when it is accompanied by a uniform standard of education (the o-ring theory) was also tested. One prediction – that the benefits of education are increasing in own education levels – is rejected using three separate tests. Although the significance of this result is not consistently maintained during sensitivity analysis, there is no evidence to support the hypothesis.

The main result is nonetheless particularly important: workplace education levels have a strong effect on own earnings, only slightly reducing the premium to own education. It does appear, however, that the earlier human capital literature may have underplayed the external effects of education on economic outcomes, particularly for workers themselves. If

regression is not strictly appropriate for the estimations reported here. Details are available from the education sorts workers into high productivity firms, this is still a 'benefit' from education – whether it is clearly a human capital benefit remains to be identified. Moreover, we find that own education is relatively less well-rewarded in workplaces which already have high education levels. This result conflicts with our expectations, and perhaps indicates stronger competitive pressures amongst educated co-workers.

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Table 1
Frequencies: Education and Outcome Variables

Education and Outcome Variables	**Code**	**Mean**	**Standard deviation**
Education Variables:			
Years of education per worker: male	e_{ijm}	13.67	3.05
Years of education per worker: female	e_{ijf}	13.76	2.96
Years of education per workplace	E_j	13.45	1.20
Interaction own–workplace education	$e_{ij}*E_j$	185.96	51.26
Dispersion of education per workplace	$É_j$	2.21	0.64
Earnings Variables:			
Log pay per hour	y_{ij}	1.94	0.47
Log median wage per workplace[a]	Y_j	9.55	0.32
Number of workers	N_i	*18304*	
Number of workplaces	N_j	*1389*	

Unweighted data. See Appendix Table 1 for definitions of variables, and for alternative derivations. [a]N_j=870.

Table 2
Log Pay Per Hour
Individual and Mean Workplace Education Levels
(GLS Random Effects)

	MALE		FEMALE	
	Coeff. (S.E.)		**Coeff. (S.E.)**	
Model [1] [a]				
Firm-level characteristics	No		No	
Own years of education e_{ij}	0.0600 (0.0012)	***	0.0640 (0.0014)	***
$?_j$	0.3710		0.3496	
R^2 total	0.3919		0.3662	
Model [2] [a]				
Firm-level characteristics	Yes [b]		Yes [b]	
Own years of education e_{ij}	0.0592 (0.0012)	***	0.0635 (0.0014)	***
$?_j$	0.2833		0.2437	
R^2 total	0.4667		0.4592	
Model [3] [a]				
Firm-level characteristics	Yes [b]		Yes [b]	
Own years of education e_{ij}	0.0561 (0.0012)	***	0.0614 (0.0014)	***
Mean workplace years of education E_j	0.1084 (0.0067)	***	0.0740 (0.0063)	***
$?_j$	0.2543		0.2246	
R^2 total	0.5032		0.4787	
Model [4] [a]				
Firm-level characteristics	Yes [b]		Yes [b]	
Own years of education e_{ij}	0.0983 (0.0135)	***	0.0523 (0.0158)	***
Mean workplace years of education E_j	0.1530 (0.0158)	***	0.0651 (0.0167)	***
Interaction e_{ij}*E_j	-0.0031 (0.0010)	***	0.0007 (0.0011)	
$?_j$	0.2517		0.2232	
R^2 total	0.5045		0.4784	
N_j [N_i]	*1389 [10578]*		*1380 [7726]*	

Unweighted data. Significance: ***1% level; **5% level; *10% level. Only full-time workers.

$?_j = (\sigma_j)^2/[(\sigma_j)^2+(\sigma_i)^2]$

[a] Included set of individual characteristics: tenure; tenure squared; age; age squared; ethnicity (1 dummy); disability (1); marital status (3); union member; temporary, fixed term or overtime worker (3).

[b] Included set of firm-level characteristics are: industry sector (8); employment size; employment size squared; ratio part-time workers; share-ownership scheme (1); profit-related pay (1); workplace older than 20 years (1); labour proportions of operating costs (3); injury rate; and teamwork (1).

Table 3
Log Pay Per Hour
Individual and Dispersion of Workplace Education Levels
(GLS Random Effects)

	MALE		FEMALE	
	Coeff. (S.E.)		**Coeff. (S.E.)**	
Model [3] [a]				
Firm-level characteristics	Yes [b]		Yes [b]	
Own years of education e_{ij}	0.0558 (0.0012)	***	0.0609 (0.0014)	***
Mean workplace years of education E_j	0.0956 (0.0075)	***	0.0609 (0.0069)	***
Dispersion: workplace years of education $É_j$	0.0359 (0.0120)	***	0.0516 (0.0110)	***
$?_j$	0.2540		0.2224	
R^2 total	0.5043		0.4826	
Model [3] [a]				
Firm-level characteristics	Yes [b]		Yes [b]	
Own years of education e_{ij}	0.0558 (0.0012)	***	0.0610 (0.0014)	***
Mean workplace years of education E_j	0.8223 (0.1113)	***	0.7487 (0.1079)	***
Squared term: E_j^2	-0.0258 (0.0040)	***	-0.0242 (0.0039)	***
$?_j$	0.2450		0.2198	
R^2 total	0.5090		0.4857	
N_j [N_i]	*1389 [10578]*		*1380 [7726]*	

Unweighted data. Significance: ***1% level; **5% level; *10% level. Only full-time workers.

$?_j = (\sigma_j)^2/[(\sigma_j)^2+(\sigma_i)^2]$

[a] Included set of individual characteristics: tenure; tenure squared; age; age squared; ethnicity (1 dummy); disability (1); marital status (3); union member; temporary, fixed term or overtime worker (3).

[b] Included set of firm-level characteristics are: industry sector (8); employment size; employment size squared; ratio part-time workers; share-ownership scheme (1); profit-related pay (1); workplace older than 20 years (1); labour proportions of operating costs (3); injury rate; and teamwork (1).

Table 4
Log Pay Per Hour
Mean Workplace Education Levels for Union and Non-union Worker Sample
(GLS Random Effects)

	MALE		FEMALE	
	Coeff. (S.E.)		**Coeff. (S.E.)**	
Only union members:				
Years of education e_{ij}	0.0516 (0.0017)	***	0.0622 (0.0021)	***
Mean workplace years of education E_j	0.0975 (0.0087)	***	0.0551 (0.0088)	***
$?_j$	0.3095		0.2668	
R^2 total	0.4646		0.4485	
Years of education e_{ij}	0.0288 (0.0181)		0.1135 (0.0244)	***
Mean workplace years of education E_j	0.0738 (0.0207)	***	0.1053 (0.0253)	***
Interaction e_{ij}*E_j	0.0017 (0.0013)		-0.0036 (0.0017)	**
$?_j$	0.3079		0.2610	
R^2 total	0.4638		0.4510	
N_j [N_i]	*908 [4888]*		*809 [3032]*	
Non-union members:				
Years of education e_{ij}	0.0591 (0.0018)	***	0.0590 (0.0018)	***
Mean workplace years of education E_j	0.1120 (0.0084)	***	0.0789 (0.0078)	***
$?_j$	0.2283		0.2514	
R^2 total	0.5365		0.4722	
Years of education e_{ij}	0.1515 (0.0198)	***	0.0135 (0.0213)	
Mean workplace years of education E_j	0.2113 (0.0228)	***	0.0342 (0.0223)	
Interaction e_{ij}*E_j	-0.0069 (0.0015)	***	0.0033 (0.0015)	**
$?_j$	0.2359		0.2531	
R^2 total	0.5365		0.4715	
N_j [N_i]	*1156 [5690]*		*1203 [4694]*	

Unweighted data. Significance: ***1% level; **5% level; *10% level.
Each estimation includes individual-level and firm-level characteristics, as per Models [3] and [4] of Table 2. See Notes to Table 2.

Table 5
Log Pay Per Hour
Mean Workplace Education Levels for Restricted Sample
(GLS Random Effects)

	MALE		FEMALE	
	Coeff. (S.E.)		**Coeff. (S.E.)**	
Only firms working in teams:				
Own years of education e_{ij}	0.0542 (0.0015)	***	0.0617 (0.0016)	***
Mean workplace years of education E_j	0.0926 (0.0077)	***	0.0665 (0.0071)	***
$?_j$	0.2468		0.2178	
R^2 total	0.4942		0.4636	
Own years of education e_{ij}	0.0925 (0.0159)	***	0.0514 (0.0181)	***
Mean workplace years of education E_j	0.1328 (0.0183)	***	0.0564 (0.0191)	***
Interaction e_{ij}*E_j	-0.0028 (0.0012)	**	0.0007 (0.0013)	
$?_j$	0.2438		0.2166	
R^2 total	0.4957		0.4633	
N_j [N_i]	*976 [7153]*		*982 [5859]*	
Only labour-intensive firms:				
Own years of education e_{ij}	0.0528 (0.0018)	***	0.0636 (0.0017)	***
Mean workplace years of education E_j	0.0987 (0.0089)	***	0.0590 (0.0078)	***
$?_j$	0.2582		0.2112	
R-squared total	0.4893		0.4546	
Own years of education e_{ij}	0.0708 (0.0200)	***	0.0780 (0.0215)	***
Mean workplace years of education E_j	0.1170 (0.0221)	***	0.0730 (0.0222)	***
Interaction e_{ij}*E_j	-0.0013 (0.0014)		-0.0010 (0.0015)	
$?_j$	0.2493		0.2071	
R^2 total	0.4901		0.4551	
N_j [N_i]	*701 [4863]*		*711 [4449]*	

Unweighted data. Significance: ***1% level; **5% level; *10% level.
Each estimation includes individual-level and firm-level characteristics, as per Models [3] and [4] of Table 2. See Notes to Table 2.

Table 6
Log Median Wage of Workplace:
Mean and Dispersion of Workplace Years of Education (OLS)

	Model [A]		Model [B]	
	Coeff. (S.E.)		**Coeff. (S.E.)**	
Quit rate	-0.1039 (0.0411)	**	-0.1130 (0.0448)	**
Absenteeism rate	-0.0052 (0.0017)	***	-0.0088 (0.0019)	***
Union workplace	0.0860 (0.0187)	***	0.0911 (0.0204)	***
International market competition	0.0317 (0.0188)	*	0.0326 (0.0205)	
Firm aged over 20 years	0.0217 (0.0152)		0.0111 (0.0165)	
Financial participation schemes	-0.0122 (0.0189)		-0.0348 (0.0204)	*
Workplace size <50	0.0348 (0.0266)		0.0162 (0.0290)	
Workplace size 50–100	0.0036 (0.0273)		0.0030 (0.0297)	
Workplace size 100–499	0.0161 (0.0279)		-0.0117 (0.0303)	
Workplace size 500–999	-0.0262 (0.0316)		-0.0355 (0.0345)	
Workplace size 1000–3999	0.0202 (0.0366)		0.0170 (0.0399)	
Workplace size 4000>	-0.0635 (0.0442)		-0.0319 (0.0480)	
Employment growth in last year	0.0189 (0.0147)		0.0154 (0.0160)	
Good relations: workers–management	0.0136 (0.0155)		0.0114 (0.0372)	
UK ownership in private sector	-0.0650 (0.0185)	***	-0.0871 (0.0201)	***
Single firm	-0.0249 (0.0189)		-0.0343 (0.0205)	*
% part-time workers	-0.0115 (0.0412)		-0.0841 (0.0445)	*
% female workers	-0.4497 (0.0400)	***	-0.4364 (0.0436)	***
>80% fixed workers	-0.0754 (0.0512)		-0.0247 (0.0557)	
Any freelance workers	0.0567 (0.0206)	***	0.0640 (0.0224)	***
Any shift work	-0.0214 (0.0165)		-0.0614 (0.0178)	***
Fewer than 5 competitors	0.0378 (0.0157)	**	0.0296 (0.0171)	*
Mean workplace years Of education E_j	0.1297 (0.0081)	***	– –	
Dispersion of workplace years of education $É_j$	– –		0.0223 (0.0024)	***
R squared	0.5840		0.5067	
Chi-squared	29.37		21.76	
N	*870*		*870*	

All data weighted using firm weights. Significance: ***1% level; **5% level; *10% level. Included in the estimation are: regional dummies (10); sector dummies (7); labour intensity of production (3); and a constant term.

Appendix 1 Definitions of the Variables

Variable and Method of Calculation

Variables Used in Estimations:

e_{ij} Worker years of education: converted from level of qualifications of: no qualifications (10 years); CSE/GCE/O-level (11); A-level (13); degree (16); higher degree (18). For those with additional vocational qualifications, one extra year was added.

E_j Mean workplace years of education: based on percentage of the workforce in each of k occupations times average years of education for that occupation from worker respondents
$(\%OCC_{jk})*(S e_{ijk}/n_k)$ $k=1\ldots9$

$É_j$ Dispersion of workplace years of education: absolute mean diff. across workers based on E_i
$S|(E_j - e_{ij}|/n_j$

y_{ij} Log pay per hour
Ln{(Median pay of *k* bands)/(no. of hours worked)}, $k=1,..12$

Y_j Log median wage at workplace
Median of $y2_j$, $j=1\ldots870$

Substitute Variables for Sensitivity Analysis [Mean, Standard Deviation]:

$E2_j$ Mean workplace years of education: based on mean of e_{ij} across workplace
$S(e_{ij})/N_j$ [13.57, 1.68]

$E3_j$ Mean workplace years of education: based on percentage of the workforce in each of k occupations times average years of education for that occupation from 1998 Labour Force Survey, split by gender
$(\%OCC_{jk})*(S e_{LFSkm}/n_{LFSkm})$ $k=1\ldots9$, m=male, female [17.32, 1.09]

$É2_j$ Dispersion of workplace years of education: absolute mean diff. across workers based on $E2_i$
$S|E2_j - e_{ij}|/n_j$ [1.97, 0.64]

$É3_j$ Dispersion of workplace years of education: absolute mean diff. across workers based on $E3_i$
$S|E3_j - e_{ij}|/n_j$ [4.02, 1.07]

$Ésq_j$ Dispersion of workplace years of education: mean diff. across workers based on E_i
$S(E_j - e_{ij})^2/n_j$ [7.19, 3,57]

$Ésq2_j$ Dispersion of workplace years of education: mean diff. across workers based on $E2_i$
$S(E2_j - e_{ij})^2/n_j$ [6.07, 3.11]

$Ésq3_j$ Dispersion of workplace years of education: mean diff. across workers based on $E3_i$
$S(E3_j - e_{ij})^2/n_j$ [21.58, 12.69]

$y2_{ij}$ Log annual earnings, using only 12 bands
Ln{Median pay of *k* bands}, $k=1,..12$ [9.88, 0.45]

See also Table 1.

Appendix 2 Summary Statistics for Selected Dependent Variables

Variable	Mean	S.D.
Selected worker characteristics:		
Tenure (years)	7.02	5.49
Union member	0.43	0.49
N_i	*18304*	
Firm-level Variables:		
Quit rate	0.15	0.20
Absenteeism rate	4.39	4.13
Union workplace	0.66	0.48
International market competition	0.37	0.48
Firm aged over 20 years	0.37	0.48
Financial participation schemes	0.58	0.49
workplace size <50	0.28	0.45
workplace size 50–100	0.14	0.35
workplace size 100–499	0.07	0.26
workplace size 500–999	0.03	0.16
workplace size 1000–3999	0.01	0.10
workplace size 4000>	0.00	0.07
Employment growth in last year	0.47	0.50
Good relations: workers–management	0.32	0.46
UK ownership in private sector	0.63	0.48
Single firm	0.23	0.42
% part-time workers	0.26	0.27
% female workers	0.49	0.29
>80% fixed workers	0.02	0.14
Any freelance workers	0.16	0.37
Any shift work	0.50	0.50
Fewer than 5 competitors	0.51	0.50
N_i	*937*	

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