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Teacher pay and school productivity: Exploiting wage regulation

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ABSTRACT

The impact of teacher pay on school productivity is a central concern for governments worldwide, yet evidence is mixed. In this paper we exploit a feature of teacher labour markets to determine the impact of teacher wages. Teacher wages are commonly set in a manner that results in flat wages across heterogeneous labour markets. This creates an exogenous gap between the outside labour market and inside (regulated) wage for teachers. We use the centralised wage regulation of teachers in England to examine the effect of pay on school performance. We use data on over 3000 schools containing around 200,000 teachers who educate around half a million children per year. We find that teachers respond to pay. A ten percent shock to the wage gap between local labour market and teacher wages results in an average loss of around 2% in average school performance in the key exams taken at the end of compulsory schooling in England.

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The importance of education means teacher productivity, and the effect of pay on teacher performance, is a central concern for governments worldwide. However, evidence on the subject is mixed (Hanushek, 2003; Hanushek, 1997). One reason for this is the difficulty in identifying the true impact of teacher pay on performance due to the endogeneity of teacher wages. Further, while experiments investigating the impact of performance pay for teachers have been plentiful (e.g. Woessmann, 2011), experimental evidence on the impact of teacher pay levels is extremely limited. Instead, one must resort to exploiting natural experiments in order to identify the impact.

One feature common to many teacher labour markets is the use of wage setting at a higher spatial level than the school. While such mechanisms avoid the cost of negotiation at school or district level, they also have an effect on the wage structure for teachers, flattening teacher wages across heterogeneous labour markets so the variation that exists does not fully reflect the wage differentials in the external labour markets in which teachers are employed (e.g. Duncombe and Yinger, 1998). The consequence is that teacher wages will be relatively worse in areas where local labour market wages are high: effectively the wage setting sets a ceiling on teacher pay. If pay matters for teaching, teacher output will be lower where the wage ceiling bites harder. We use this insight to test the effect of teacher pay on school performance. Our research design exploits the centralised pay setting of over 200,000 teachers who teach around half a million children each year in the English public (state) school system and a national system of pupil testing and assessment of school quality.

In England pay for teachers is set by a central review body that sets pay scales in which there is very limited regional variation.[1] However, as regional pay differences are considerable in the private sector even after controlling for human capital characteristics and other factors (Bulman, 2002) this creates a gap between local labour market wages and the regulated wages paid to teachers. We use this to examine the effect of exogenous local wage shocks on the quality of schooling in all public (state) secondary (equivalent to US middle and high) schools. Our primary measures of performance are based on the performance of pupils in the high stakes exams taken at the end of compulsory schooling. We complement this by examining quality as measured by in-depth assessments made by the national school regulatory body. We use a data source on pupil performance that allows us to control for the initial ability of the school intake, time varying attributes of the school body and time constant pupil, family and neighbourhood characteristics that may affect levels of attainment independently of teacher effort. We examine some of the potential pathways by which wages may results in greater pupil attainment including the cross-sectional

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[1] Collective wage setting is a feature of many education systems. For example, in the USA, as of 1988, all but seven states had passed a law either allowing for the right of teachers to bargain collectively or explicitly requiring districts to bargain with teachers' unions (Lovenheim, 2009). Wages are also centrally negotiated between the state or national government and the teaching unions in many European countries (Galgóczi and Glassner, 2008).

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relationship between teacher tenure and outside wages and seek to rule out that our findings are explained by pupil and parental, rather than teacher, responses to wage shocks.

We find a ten per cent shock to the gap between the local average outside wage and the teacher wage results in an average loss of about 2% in the high-stake exams taken at the end of secondary school and a 5% loss in a key metric by which schools are assessed by the regulator, the public and the government. The loss is greater in schools that are located in areas where the ceiling bites harder and for schools that have no control over the employment conditions of teachers. We find that a measure of teaching quality from inspections by the national school regulator is lower where wage shocks are higher and that higher outside wages are associated with lower lengths of tenure. The results are robust to a wide range of specification tests, and to alternative explanations relating to other channels through which the outside wage might affect pupils' performance.

Our paper contributes to the large body of evidence on school performance and the teacher labour market. There is the large and growing literature on the impact of teacher pay on school performance. Research on the effect of teacher salaries on school level pupil outcomes initially suggested that this was mixed. For example, Hanushek, 2003, reports that only 20% of 119 estimates found a positive effect of teacher wages on school performance. But later research has found more response to wages. For example, for the USA, Loeb and Page, 2000, find teacher wages to be a significant determinant of pupil outcomes, estimating that a 10% increase in teacher wages would reduce dropout rates in the US by between 3 and 6%, while Hendricks, 2014, finds that paying teachers more improves student achievement through higher retention rates. Dolton and Marcenaro-Gutierrez, 2011, finds both relative and absolute levels of teacher salaries exert an important influence on pupil performance using data on 39 countries. Another focus has been the impact of teacher pay on the labour supply of teachers, including entry, duration of teaching, mobility of teachers and teacher absenteeism. Examples include Murnane and Olsen, 1990; Dolton, 1990, 2006; Dolton and van der Klaauw, 1995; Figlio, 1997; Barr and Zeitlin, 2010 and Leigh, 2012. All of these find an effect, though Hanushek and Rivkin, 2006, stress that teacher responses to alternative wages may be muted compared to other workers. A separate strand in the education literature examines the effect of differences in the educational cost across areas on performance from the USA. This research makes the point that centrally determined financing formulae, intended to help equalise finances between areas have differential ability to raise funds (e.g. Duncombe and Yinger, 1998; Hoxby, 2001), may also have unintended consequences, for example on student performance (e.g. Duncombe and Yinger, 2011; Eom et al., 2007) and teacher attrition (Ondrich et al., 2008).

More generally, labour economists have long been interested in the impact of labour market changes on firm performance. Theories of "efficiency wages", for example, suggest that improvements in the labour market outside the firm's boundaries could lead to decreased productivity within a firm because there may be more shirking (Shapiro and Stiglitz, 1984), a loss of high quality workers (Weiss, 1980) or perceptions of inequity (e.g. Akerlof, 1982; Mas, 2006). It is difficult to test these ideas in an unregulated labour market. Where pay is set by regulation, however, there is a wedge between inside and outside wages that enables identification of the impact of external labour markets on firm outcomes. So we can effectively use regulation to generate exogenous variation in factor prices. In this design, two papers are antecedents to ours. The first is Cappelli and Chauvin, 1991, who show that higher outside wages increase shirking in a US auto manufacturer. Like our paper, the authors exploit the fact that the union contract stipulates the same pay rates across diverse metropolitan areas. But their sample is small and is a cross section of 78 plants, whereas we have a much larger panel of around 3000 schools. The second, and closest, paper is Propper and van Reenen, 2010, who examine the impact of centralised wage regulation for nurses on death rates following emergency admissions for heart attacks to English hospitals between 1996 and 2005. They find that the aggregate death rate rises due to the regulation and that removal of centralised wage setting would have positive welfare consequences. Our paper complements theirs by focusing on another key part of state provision: the education of around 3 million of England's children per annum.

The remainder of the paper is as follows. Section 1 outlines the institutional background of education in the UK, Section 2 provides information on the data used and Section 3 discusses the methodology. The results and a range of robustness checks are given in Section 4. Section 5 studies potential mechanisms through which the outside wage could operate. Section 6 presents a simple calculation of the potential gains from removing wage regulation and Section 7 offers concluding comments.

1. Institutional background

Education in England is compulsory between the ages of five and sixteen. While children can be educated privately, the public (state) system dominates. State sector pupils attend primary school from age five to eleven and secondary school from age eleven to sixteen. Pupils can then stay on for a further 2 years to get qualifications that allow them to undertake university level education. In 2007 approximately three million young people (around 84% of eleven to sixteen year olds) were attending public secondary schools. In each secondary school there are five (or seven if the school provides education up to 18) separate age cohorts within the school at any one time.

Pupils take nationally set exams at four points during their ages of compulsory school attendance. At primary school these are Key Stage 1 (KS1) at age 7 and Key Stage 2 (KS2) at age 11 (the year of exit), in Mathematics, English and Science. In secondary schools these are Key Stage 3 (KS3) exams at age 14 in Maths, English and Science and Key Stage 4 (KS4) examinations in multiple subjects (typically between eight and twelve) at the end of compulsory schooling at age 16. We focus on KS4 (GCSE) examinations as our measure of school performance as these are high stake examinations. For pupils they determine progress into education after age of 16, as a minimum of five pass grades required to continue on to further education, are used by parents to choose secondary schools for their children, by the media to rank school performance to create school 'league tables' and by local and central government to identify 'failing schools'.

Schools in England are heavily regulated by central and local government. Summary statistics on school performance have been published annually since the early 1990's. The key measure used to compare schools has been the number of pupils attaining at least 5 good grades in the KS4 exams (known as 5 A*-C GCSEs), though the number of metrics published increased during the mid- and late 2000's. In addition, in-depth assessments of the quality of the school are undertaken by the schools regulator, OFSTED. Each school is inspected roughly every five years. Inspections often last several days. On the basis of these site visits, OFSTED publishes a report rating the school's performance on numerous dimensions, including an overall rating of the school and an assessment of teaching and learning at the school. More details on these metrics are provided below in Section 3.1.

1.1. Teacher pay in England

Teacher wages are set by Local Education Authorities (LEAs) based on guidelines issued by the national Government Department for Education.[2] Despite the existence of four pay bands ('Inner London', 'Outer London', 'The Fringe' and 'The rest of England'), teacher wages have exhibited very little regional variation relative to private sector wages since the early 1970's. For example, the average teacher wage

[2] LEAs are geographically coterminous with the primary and larger units of local government, the Local Authority (LA). We use the term LEA when discussing education/school issues and data and LA when discussing data available at this level.

differential outside the South East of England and Inner London is approximately 15%, while the equivalent private sector wage differential can be as large than 45%.[3] Since its formation in the 1990's, the School Teacher Review Body (STRB), an advisory board which comments on teacher conditions and pay, has frequently argued that the Department for Education should be doing more to encourage locally flexible wages.[4] Although an increasing amount of discretion over wages has been granted to LEAs, and more latterly schools, they have not utilised the option (Sibieta, 2015). This is possibly due to the fact that local authorities have faced strong national teaching unions for many years, making the costs of local negotiations high for a single school or local authority (Zabalza et al., 1979).[5] Further these costs are incurred before any gains are realised, so schools and the elected local authorities may place greater weight on current costs versus longer-term potential gains. In addition, there has been very little scope for schools to provide differential non-pecuniary benefits for teachers - there is no variation in holidays and contact hours are generally fixed.

Recent changes to the schooling system in England which have come into play in the second decade of this century have given schools potentially more power over wages and teacher conditions. The UK government has encouraged the setting up of 'free schools' and academies in England. Such schools are free of LEA control and able to choose their own curriculum. While the programme was started under the Labour administrations which operated upto 2010, before the school year 2008–9 there were less than 100 such schools. The programme really accelerated after 2010 (Sibieta, 2015). To avoid contamination we confine our analysis to before 2008 (we discuss the data in detail in Section 3.1).

1.2. How centralised pay may affect school performance

We follow Hall et al. (2008) and propose a simple dual-region model of the English market for teachers. In this market, 'The North' has lower living costs and fewer outside options relative to 'The South'. Even when controlling for worker composition, the local private sector wage is therefore lower in the North. Because of these factors, for each given wage, teacher supply is higher in the North than in the South. An ideal pay structure would therefore allow differential wages in each region to equalise supply and demand. As shown in Fig. 1, by setting the centrally regulated wage to be constant across the two regions at W^C, even if on average the regulated wage is at equilibrium, a wedge exists between it and the equilibrium wage at the regional level. In this model the regulated wage acts as a pay ceiling in the South.

This model presents the case of an invariant regulated wage across regions. In England there is some wage variation across four large geographical regions but, as can be seen from Fig. 1, unless the regional variation is such that the teacher wage in the South is set equal to W^S and the teacher wage in the North is set equal to W^N, the nature of the problem persists; disequilibria in local markets will remain, affecting teacher supply in certain regions. Based on the lack of variation that we observe in teacher wages compared with private sector wages (and indeed the focus of the STRB on the issue), it is highly unlikely that the regional variation in England goes far enough.

This model highlights the possibility of insufficient supply in high wage areas, but Fig. 1 would be unchanged if it were referring to the supply of quality teachers, or indeed the supply of effort of teachers; in either case there would remain a shortage in the South as a consequence of the invariant wage.[6] This highlights that the effect of an invariant wage on school performance in high wage areas could work through a number of mechanisms which relate to both lower effort and the sorting of lower quality teachers to relatively lower paid areas (Lezear, 2000). In terms of sorting, problems may arise in recruitment and retention. First, in England, Dolton (1990) finds that wages are an important factor in recruiting good teachers and Ma et al. (2009) find a negative relationship between relative teacher wages and posted Local Authority level teacher vacancies. Second, public sector wage increases in the UK have been shown to improve the qualifications of new public sector workers (Nickell and Quintini, 2002), suggesting the negative effect may not be seen just through vacancies, but also through reduced teacher quality. In terms of effort, teacher quality has been shown to be important for school performance (Barrow and Rouse, 2005; Rockoff, 2004; Benton et al., 2003; Rivkin et al., 2005; and for England, Slater et al., 2012) and teachers have been shown to be adversely affected by lower quality colleagues and by high turnover rates (Ronfeldt et al., 2011). There is scope for reductions in effort in response to lower relative wages as the nature of teaching in England means a large proportion of the work is discretionary (time spent lesson planning, engagement in after-school programmes, time invested worrying about particular children).

Two early English studies of school performance suggest that relative pay is important but neither test this hypothesis. Gordon and Monastiriotis (2007) investigate neighbourhood and regional effects on education performance and conclude that schools from some of the most affluent areas perform worst relative to expectation. They attribute this to 'crowding out' of public sector activity in affluent areas. Zabalza et al. (1979) examine English secondary schools in the 1960s and find fewer qualified teachers and higher turnover rates in London compared to the rest of the country and attribute this to the poor relative wages in London.

2. Methodology

We examine the relationship between local wages and school level productivity. Our main measure of school productivity is value added by the school in key national exams at the end of compulsory schooling. We exploit the fact that there are national exams taken by all students immediately prior to secondary school entry to control for initial ability of pupils. In a set of extensions we also explore other measures of school productivity.

Following Loeb and Page (2000), a simple education production function for value added at school level which considers the importance of controlling for alternative labour market opportunities is:

$$y_{i,t} = \alpha + \beta\left(\ln W^I_{i,t-1} - \ln W^O_{i,t-1}\right) + \rho y_{i,t-5} + \gamma' X_{i,t} + \mu_t + f_i + \epsilon_{i,t} \quad (1)$$

where y_{it} is the average exam score at school leaving age (Key Stage 4) for school i at time t, and $y_{i,t-5}$ is the average exam score at entry into the school at age 11 (Key Stage 2). W^I_{t-1} is the inside wage, W^O_{t-1} is the outside wage, X is a vector of controls at cohort (the year group), school and Local Authority levels), μ_t is a set of time dummies and f_i is a time invariant school fixed effect.

In our case, the inside wage is the regulated wage which is set over a large region (there are four in the whole of England, a country with a population of around 53 million). The outside wage is estimated from wages in the local labour market. The use of a one period lag in wages in Eq. (1) is problematic in the context of school production in England,

[3] Author calculations from ASHE (for non-teacher wages) and the School Teacher Review Body reports (for teacher wages).

[4] STRB annual report (2010).

[5] The number of teachers in state schools is around 438,000. The largest union, the National Union of Teachers, has around 325,000 members making it the largest teaching union in Europe. A second union covers most other teachers in school. Both unions strongly support national pay frameworks (e.g. their recent submission to the pay review body http://www.teachers.org.uk/files/nut-supplementary-submission-to-the-strb-november-2014.pdf; http://www.nasuwt.org.uk/consum/groups/public/@salariespensionsconditions/documents/nas_download/nasuwt_010779.pdf).

[6] Propper and Van Reenen (2010) present a more complex two sector, two skills model in which individuals can move sector or region.

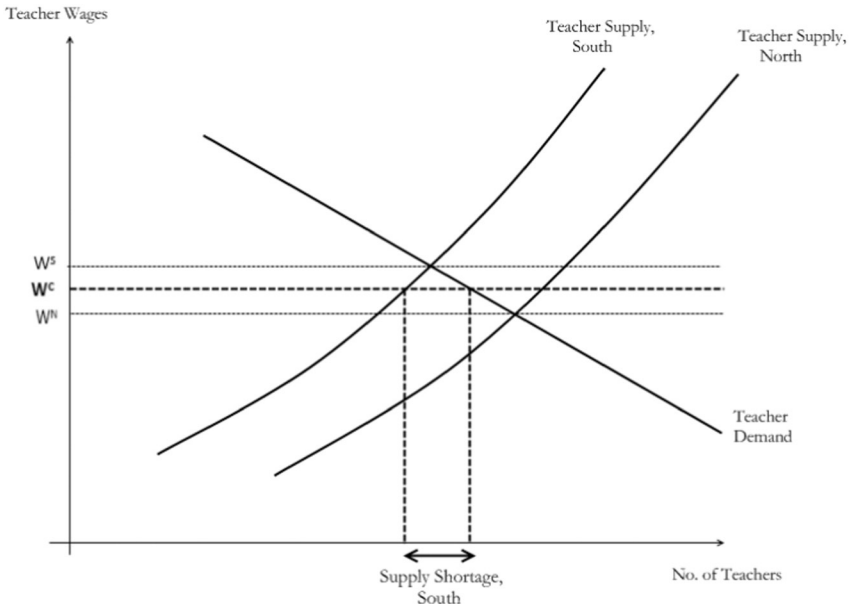

Fig. 1. The Impact of Wage Regulation on Labour Supply.

where pupils normally attend the same secondary school for five years. This has two consequences. First, since education is cumulative and final examination results will depend on the education a pupil received in all of the years they attended the school, it is likely that there will be long lags in the effect of the outside wage.[7] Thus a regression with only one lag in wages is likely to suffer from omitted variable bias. While in principle we could estimate Eq. (1) with 5 lags of wages, in practise the outside wages in year *t* are likely to be not dissimilar to those in year *t-1*, so identification of the separate effect of each year's wages will be difficult. Second, since teachers teach children across year groups, different year groups within one school will be subjected to the same shocks. This is likely to create high levels of serial correlation in the outcome data. In Appendix B we examine the impact of these two problems. These estimates show the problem of estimating a full dynamic model, but they also confirm that in our data there appears to be a negative relationship between outside wages and value added for almost all lags of the wages, and that this increases over time.

Our solution takes into account that pupils are in secondary schools for five years between entry and sitting KS4 exams. To get round the problem that a shock in year *t* will affect all children in the school, we restrict our estimation sample to have a five-year gap between each school level observation of performance. This means there are no overlapping cohorts of pupils contributing to each school level observation, thus reducing the impact of serial correlation across cohorts. To address the potentially long lag structure, we impose the assumption of common effects in the lagged wages and estimate the effect of an average outside wage, defined over a five-year period (i.e. from *t-1* to time *t-5*). This has the additional advantage of averaging away some of the noise in the annual wages. The model we estimate is:

$$KS4_{i,t} = \alpha + \beta\left[\left(\frac{1}{5}\sum_{k=1}^{5} W^{O}_{i,t-k}\right) - W^{I}_{i,t-1}\right] + \rho KS2_{i,t-5} + \gamma' X_{i,t} + \mu_t + f_i + \epsilon_{i,t} \quad (2)$$

The explanatory variable of interest is the gap between the school outside wage averaged over five years from *t-1* to *t-5* and the regulated inside wage at time *t-1*. The dependent variable is school level mean KS4 points obtained at time *t* for school *i*. $KS2_{i,t-5}$ is the intake performance (measured in the last year of primary school) of the pupils who take their KS4 in year *t*. This boils down to regressing changes in exam scores on changes in outside wages, keeping constant any relevant X_{it} and baseline exam scores. Conditioning on the fixed effects at school level, this is like a difference-in-difference analysis. A disadvantage is that as school performance data which contains both KS4 and KS2 scores is only available from 2002 onwards we only have two observations per school, in 2007 and 2002, matched to wage data starting in 1997. However, we have a large sample of schools, and the two observations per school allow us to control for time invariant heterogeneity at school level. The outside wages are estimated from local area data, so to deal with this we bootstrap standard errors. Finally, as outside wages are labour market variables and not school level variables, we cluster standard errors at the (larger) local labour market.

3. Data

We use several sources of administrative data. At the core of our analysis is data on school performance matched to data on the gap between local outside labour market wages and the regulated inside wage. To test robustness and to examine the potential pathways by which wage regulation may affect school output we augment this with other data on the local labour market and teacher tenure. This section describes our data: details of sources and the years we use are provided in Appendix A, Table A1.

3.1. School performance data

Our main measure of pupil performance at school level is taken from the Pupil Level Annual School Census (PLASC). This dataset records the performance of all pupils in national exams in all 3285 public (state) secondary schools in England. PLASC began in 2002. We use data from the inception of PLASC to 2007. We confine ourselves to this window to avoid any potential contamination from schools which operated as academies (there were only 85 in 2007).[8]

[7] In principle, there could even be an effect of wages prior to entry into school of the cohort if this affected the teachers that taught the school cohort (for example, if wages led to staff leaving and the remaining staff being demoralised as a result).

[8] As the large increase did not occur until 2011 (Sibieta, 2015) we can also rule out any anticipation effects.

Pupils can take up any number of KS4 exams, with a minimum of one and a conventional maximum of around fourteen, in a range of subjects including Mathematics, English language, English literature, Science subjects, and History.[9] KS4 exams are graded from A* to G, and these grades are translated into points, such that an A* is worth eight points, an A is worth seven, a B is worth six, and so on. We use the total number of points that a student obtains (i.e. points from each exam summed across all the exams they take), averaged at school level, as our key measure of output of the school. To control for the effect of pupil type (including effects of peers in the school), we control for the attainment of the same cohort of pupils immediately before they entered the secondary school.[10] This is the pupils' average point score in the KS2 exams, also from PLASC. KS2 exams are graded from 2 to 5, and are taken in Mathematics, English and Science.[11]

In analyses of other measures of performance we examine the proportion of pupils in the school who achieved 5 GSCEs at grades A*-C or better; the average number of KS4 exams taken by pupils (all from the PLASC dataset); and the number of pupils excluded from school (from the Dept. for Education). We also use measures of school performance derived from the in-depth inspections of schools undertaken by the government schools regulator (OFSTED). OFSTED undertakes expert in-depth inspection of each school to provide a published assessment of the quality of each school. These assessments take place over a number of days and are intended to 'net out' any pupil or parental effect. The school's performance is rated on numerous dimensions, including an overall rating of the school and an assessment of teaching and learning at the school.[12] Both are rated on a four-point scale from 1 (outstanding) to 4 (inadequate). Given the frequency of inspections, these data are available for only a sub-sample of the schools in our main analysis. We use inspection data from 2002 to 2008.

In our analysis of pathways, we use data on teacher tenure at school level from the School Workforce Census. This is a recently released administrative dataset from which the proportion of teachers in a school who are in post for less than a year, and the proportion that have been in post for over 10 years can be extracted. It has only, to date, been released for 2010.

3.2. Wages and employment data

Our key measure is the 'wage gap', specifically the difference between 'outside wages' and 'inside wages'. Our 'outside wage' measure is intended to measure the alternative private sector wage which teachers could command. We define the outside wage for each school as the average wage of all Local Authorities (LA) whose headquarters is within a 30 km radius of the school. This circle around the school represents a 'travel to work' area (TTWA), in which teachers at the school could seek alternative employment.[13] In some areas, there are as many as 45 LAs within this radius, whilst in many others there is just one as LAs differ in geographic size. For schools where there is not a headquarters of a LA within the 30 km radius (or the wage data is missing for the LAs within that range) the nearest LA with wage data is allocated to a school, provided that LA is within 60 km of the school. If the nearest LA with wage data is outside that distance, the school is excluded from our analysis.[14]

The local wage data are from the Annual Survey of Hours and Earnings (ASHE) dataset, a 1% sample of all employees in Great Britain, covering approximately 300,000 workers per year, sampled in April of each year which provides wage data at Local Authority level. The publicly available dataset contains average wages, split into manual and non-manual, part and full time. As our measure of outside wages we use (the log of) the full time male non-manual hourly earnings.[15] To construct the lagged five-year average wage for each school we use the average of outside wages from *t-5* to *t-1* for all LAs that fall into the TTWA of the school. The five year gaps between our outcome observations in Eq. (2) mean we use average wages from 1997 to 2001 and 2002–2006. In robustness checks we use a more complex measure of outside wages which corrects wages for local labour market composition. The correction uses Labour Force Survey (LFS) as ASHE does not contain the necessary data to make this correction.[16] Details are provided in Appendix B. Inside wages are from the Department for Education Teacher Pay and Conditions Handbooks.

For our 'inside wages', we use teacher wage data at the payband level to avoid concerns over endogeneity.[17] We use the (log of the) inside wage lagged for one year, so inside wages are for 2006 and 2001. The results are robust to using contemporaneous inside wages (for 2007 and 2002). In analyses of heterogeneity we define large 'outside wage regions' on the basis of the long run level of outside wages, as measured in ASHE. We group the 10 Government Office Regions (GORs) in England into three (details in Appendix Table A2, Panel (A)) and assign each school to a single 'outside wage region'.[18] In extensions to our main analyses, we examine the impact of outside wages and employment prospects for different groups (the youth labour market, manual workers) in the outside labour market on school performance. These wage and employment data are from ASHE.

3.3. Controls

The PLASC data contain information on the final-year (age 16) composition of pupils. But our identification approach means that results with and without controls should give the same estimates and pupil characteristics may be endogenous. So we initially present results with no controls other than prior attainment. We then use a small set of controls (those that we find are associated with value added controlling for outside wages) to allow for the effect on the standard errors of heterogeneity across pupil type. The controls we include are Key Stage 2 (KS2) scores, percentage of male students, percentage of students eligible for free school meals (FSM), and the percentage of severe special educational needs students (SEN) We also use this set of pupil controls to test the key identification assumption in our design. We also include school expenditure per pupil (EPP) to address the concern that wages might differ between schools across different paybands, but that school resources might not.[19]

3.4. Data description

Summary statistics for all variables we use are in Table A3. The table shows the range of KS4 points across school is large, with a minimum

[9] There is no official maximum, although taking more than fourteen is rare.

[10] There are more primary schools than secondary schools so pupils in any secondary school will be from a number of different primary schools.

[11] PLASC links data at the pupil level over time. It was preceded by the Annual School Census (ASC) which was at school level. KS2 scores were only available for primary schools in ASC i.e. they were not linked to the secondary schools that pupils attended. Thus school level value added cannot be observed before 2002.

[12] Schools are given an overall rating. Within this there are four categories (Achievement & standards/Personal Development & Well-Being/Quality of Provision/Leadership & Management). Teaching and Learning is a subcategory of Quality of Provision. Pre-2005 a 7-point scale was used to rate schools and from 2006 a 4 point scale. As few schools received above 4, we capped scores at 4 for comparability across time.

[13] Propper and van Reenen (2010) use the same labour market definition for nurses in England.

[14] The small distances in England mean only nine schools are dropped from the sample. In robustness tests below we examine the impact of using different radii to define the TTWA.

[15] Our results are robust to use of male and female (separately) weekly wages.

[16] We also use the LFS to derive counterfactual wages for our calculations of the costs of wage regulation.

[17] Specifically, we use the salary point M6 on the teacher pay scale as our inside wage.

[18] Long run wages based on ASHE average non-manual full time weekly wages.

[19] The results are little affected by this control.

score of zero and a maximum of 99. The mean is just under 44. KS2 scores are in different units to KS4 and have a mean of just under 27. The log of the outside wage, averaged for each school over a five-year period, has a school level mean of 7.134, which equates to an average salary of £29,524 per annum.[20] The log of the inside wage has a mean of 6.43 and on average the wage gap is 0.704. All variables, particularly the wage gap, exhibit considerable within group variation, indicating change over time within schools.

Table A2, Panel (B) shows the absolute growth in the (nominal) level of wages by the three outside wage regions for the whole period covered by our data, 1997–2006. For the whole period, absolute growth is highest in the high outside region at £12.2 K and lowest in the low wage region at £8.4 K. In the first sub-period, the growth is again monotonic across the three outside wage regions. In the second sub-period, the growth is highest again in the high outside wage region and very similar in the medium and low wage regions. Given this, there is a close mapping between the definition of broad outside wage region in terms of long run levels of wages and a definition of outside wage areas in terms of growth rates in wages.[21]

Table 1 presents cross sectional estimates year by year between the (log of) the wage gap (lagged one year) and school average GCSE performance. We include controls for mean KS2 scores at intake and local authority fixed effects. The estimates are the change in average GCSE points per pupil associated with a 10% increase in the outside wage. All the cross-sectional associations are negative, though not all are statistically significant. The association is largest in 2005 at just over half a GCSE point lost per student.

Table 1
Cross Sectional Associations between wages and KS4 performance.

Year	2002	2003	2004	2005	2006	2007
Wage Gap	−0.390**	−0.220	−0.545**	−0.620***	−0.464**	−0.152
	(0.193)	(0.247)	(0.243)	(0.231)	(0.220)	(0.281)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
LEA dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	2964	2985	2998	3018	3019	3035

Dependent variable is school average KS4 score. Wage gap is the outside TTWA wage minus the inside wage lagged by one year. Inside teacher wages vary at the teacher payband level. Controls in all regressions for Key Stage 2 (KS2), %Free School Means (FSM), %Male, %Severe Special Educational Needs (SEN) and Expenditure per pupil. Sample sizes vary by years due to school opening and closure. Standard errors are robust, clustered at TTWA level (of which there are 529 clusters) and bootstrapped with 1000 repetitions. They are reported in the parentheses. * significant at 10% level, ** 5% level, * 1% level.

3.5. Test of assumption that school fixed effects can be differenced out[22]

The model we estimate is a model of value added i.e. we condition on the prior attainment of the pupils who are in the school at age 16. We assume that the school fixed effects in Eq. (2) are fixed over time and so can be differenced out. This assumption may be violated for several reasons. The most important of these is that the cohort of students whose KS4 achievement is measured in 2007 is different from the cohort whose KS4 achievement is measured in 2002. This is particularly a problem in our context if within school differences in cohorts are correlated with changes in wages and different types of student different in expected growth in achievement. We seek to overcome this, in part at least, by defining the outside wage as covering a large area compared to a school. The travel to work area in our analysis is 30 km round the school. Thus the wage we use is not the wage simply of workers who live locally to the school. This means that the outside wage is less likely to be a measure of the wage of parents of the children in the school. We also control for a number of observed characteristics of the children in the each of the two cohorts.

However, we may be concerned that our design is not robust and here we implement a direct test of our assumption that changes in the outside are not correlated with observable changes in the school cohorts. We regress, at school level, the initial level of the achievement of the school cohort $KS2_{i,t-5}$ plus the other covariates pertaining to the school cohort, on the outside wage, controlling for school fixed effects and time dummies.[23] We present results for all years 2002–2007 and also for 2002 and 2007 only. In our main estimates of Eq. (2), we use two observations per school of value added. The dates of these are 2007 and 2002 and therefore the school level covariates we use in our regression are 2006 and 2001. The results are in Table A4. The table presents the estimates of KS2*i*,*t-5* and the other student characteristics we use in the main results on the outside wage along with the joint *F*-test of all the covariates. Column (1) presents results for the whole period and column (2) for 2002 and 2007. The results show that the *F*-tests on the covariates in both columns are small and insignificant. In addition, none of the student characteristics are significant associated with the outside wage across the two regressions.

It is possible that areas with high wage changes experience differential changes in school composition over the period than areas that had lower wage changes. To examine this we repeat the analysis above, but this time splitting the sample split into three groups according to the growth in outside wages over the period.[24] This split into three regions according to wage growth rates has very close correspondence to a split in terms of long run levels of wages. The results are presented in columns 3–8 of Table A4. This shows that there is a little more association within 'growth in outside wages' regions between the pupil characteristics and the level of wages, but even here only two of the *F*-tests are statistically significant at the 5% level. Further, the patterns of association between changes in pupil characteristics and changes in wages is not consistent across, or within, regions. For the highest 'growth in outside wages' region, wage growth is associated with an increase in the proportion of children with parental low incomes, as measured by eligibility for free school meals. In the lowest 'growth in outside wage' region, an increase in wages is associated with a fall of pupils with special needs, which might also be taken as a marker of low parental income. But in this region a growth in wages is also associated with a fall in performance in the exams taken immediately prior to school entry (Key Stage 2).[25]

3.6. Tests of common trends

Our analysis is essentially a difference-in-difference (DiD) estimation in which we have multiple areas and two years per school. To check our common trends assumptions we regress the growth in

[20] Annual average salary calculated from the level of the school TTWA wage.

[21] There is heterogeneity in growth rates in LEAs in the middle outside wage region. For example, of the 30 LEAs (of a total of 148) which experienced the highest wage growth 1997–2006, 11 are located in the middle outside wage region. These LEAs are all outside the areas given the highest uplilft by the by the teachers pay Review Body. The LEAs are Halton, Blackpool, Bath and NE Somerset, North Somerset, Plymouth, Poole, Wiltshire, Luton, Cambridgeshire, Essex, Hertfortshire.

[22] We are grateful to an anonymous referee for making this issue clear and for suggesting tests to address this. This section draws heavily on their help.

[23] We focus on outside wages, rather than the wage gap, as the differential between areas in regulated wages does not change very often. Thus any differences in the socio-economic conditions of an area will be driven by differences in outside wages.

[24] The wage regions split by the growth, rather than the level of outside wages differ slightly, though there is a high correlation. By levels, the wage regions are, High: Inner London, Outer London, South East; Medium: East South West, North West; Low: East Midlands, West Midlands, North East, Yorkshire. By growth, they are, High: Inner London, Outer London, North West, Yorkshire; Medium: West Midlands, South East, East Midlands; Low: South West, North East, East.

[25] This pattern of association also makes the direction of bias difficult to sign. On one hand, falls in KS2 may indicate that the pupil body is becoming more difficult to educate as wages rise and our results will be biased away from zero. On the other hand, falls in the number of students with special needs may indicate the student body is becoming easier to educate, so our results will be biased towards zero.

Table 2
School Productivity.

	Key Stage 4				Five or more A*-C	
	OLS		FE		FE	
	[1]	[2]	[3]	[4]	[5]	[6]
Wage Gap	−0.471**	−0.475***	−1.115**	−1.032**	−0.273***	−0.247***
	(0.185)	(0.183)	(0.448)	(0.455)	(0.090)	(0.090)
KS2	0.464***	0.454***	0.215***	0.196***	0.047***	0.042***
	(0.007)	(0.009)	(0.018)	(0.019)	(0.003)	(0.003)
Controls	No	Yes	No	Yes	No	Yes
School FE	No	No	Yes	Yes	Yes	Yes
No. Schools	2949	2949	2949	2949	2949	2949
N	5898	5898	5898	5898	5898	5898

Key Stage 4 mean is the dependent variable for columns [1]-[4], Five A*-C is the dependent variable in columns [5] and [6]. All regressions have 2 observations per school, with the school outcome in 2002 and 2007. Controls in all regressions for Key Stage 2 (KS2), %Free School Means (FSM), %Male, %Severe Special Educational Needs (SEN) and Expenditure per pupil. Wage gap is averaged TTWA wages over five years (the "outside wage"), lagged by one year (i.e. 1997–2001 and 2002–2006) minus inside teacher wages lagged by one year (i.e. 2001 and 2006). Inside teacher wages vary at the teacher payband level. Standard errors are robust, clustered at TTWA level (of which there are 529 clusters) and bootstrapped with 1000 repetitions. They are reported in the parentheses. * significant at 10% level, ** 5% level, * 1% level.

outside wages between 2002 and 2006 at the LEA level on the average characteristics of school pupils (jointly) in 2002 and the level of total KS4 points per pupil in 2002 (the earliest year for which these data are available). Differences in outside wage growth that are associated with the initial level of covariates or school output could indicate that areas that differ in terms of wage growth also differ in terms of unobservables and threaten our identification strategy. The results are presented in Appendix A, Table A5 columns [1] and [2]. The results show that there are no significant associations between the 2002 characteristics and the subsequent wage growth at LEA level.

While the baseline school covariates and school level average GSCE points are not available before the release of PLASC in 2002, there is available data on the performance at school level on the 5 A*-C metric. As a further test, we examine the association between this metric in 1997 with subsequent wage growth 1997–2006. This therefore spans the full period covered by our wage data (as our analysis uses wages averaged over 5 years, lagged once). The results are presented in Appendix A, Table A4, column [3] and show no association between baseline performance and wage growth. The subsequent columns of Table A4 repeat these analyses at the level of the three outside wage regions. Again, we find no association between baseline covariates or baseline school performance and subsequent wage growth. We conclude that our design assumptions are likely to be satisfied.

4. Results

4.1. Baseline results

Table 2 presents estimates of the effect of wages on school productivity as measured by value added on KS4 test scores. Standard errors are robust, clustered at the TTWA level and bootstrapped to allow for the estimation of outside wages.[26] Columns [1] – [4] presents the results for value-added (total exam points per pupil controlling for initial intake scores). Columns [5] and [6] present results for the percentage of pupils who achieved at least 5 A*-C GCSEs (also with controls for initial intake scores). Columns [1] and [2] present OLS estimates. The remaining columns present fixed effects estimates. The first of each pair of estimates has no controls and the second includes those pupils and school level covariates which are associated with test scores after controlling for school fixed effects and prior attainment.

The table shows all coefficients on the wage gap are negative and significant. The increase in size between the OLS and fixed effects estimates in Columns [1] and [2] indicates that controlling for omitted school level factors is important.[27] On the other hand, the effect of controlling for time varying school level covariates is small, supporting the appropriateness of our identification strategy, as if this is correct the covariates should only affect the standard errors.

The coefficients represent the estimated change in the outcome associated with a 10% increase in the gap between the five-year outside average wage and the inside wage. Column [4] indicates a loss of approximately 1 GCSE point per pupil in value added in response to a 10% increase in the wage gap, which is equivalent to dropping one GCSE grade in one subject or around a 2% average fall at the mean of 44 points. Column [6] indicates a fall of around 2.5%age points in the proportion of pupils achieving 5 or more A*- Cs, which equates to a 5% fall at the mean of 56.5 percent. Thus the estimates suggest that a positive shock to outside wages leads to a small, but non-trivial, fall in both measures of school productivity.

We now subject our results to a battery of tests. We begin by testing the robustness of the results to the definition of our key variable, the outside wage. We then allow for correlation of errors across schools within labour market areas. We then test the salience of our design by examining whether the effects of regulation are larger in various settings in which the wage ceiling should have greater bite. Finally we examine robustness of the results to potential gaming by schools that may be correlated with the outside labour market shocks.

4.2. Alternative specification of the outside labour market

Our primary specification uses the average of the one year lagged gap between the (five year averaged) non-manual male outside wage for a TTWA defined as 30 km round the school and the regulated (inside) wage. We subject these key measures to a number of robustness tests. First, in the spirit of a placebo test, we check that there is less response to a less relevant measure of outside wage. As teachers are graduates, if the outside wage has an effect on their performance, they should be less likely to respond to shocks to the wages of less skilled workers. In row [2] of Table 3 we replace the non-manual wage with the wages of less skilled workers (manual workers). We find the coefficient on the wage gap more or less halves and is insignificant at conventional levels.

Second, we check robustness to the definition of the TTWA. Our main specification uses a radius of 30 km round each school to define

[26] We have almost 3000 schools and more than 500 clusters (TTWAs).

[27] The increase in estimates between OLS and the fixed effects specification suggests an unobservable factor that is positively correlated with both outside wages and school performance. An example might be a board of governors (the quality of the board of governors could be greater in high outside wages, improving school performance), or the quality of the head-teacher, whose wages are not subject to regulation.

Table 3
Robustness Checks.

		FE estimate on wage (se)	
[1]	Baseline Estimate	−1.032** (0.455)	5898
Wage and labour market tests			
[2]	Manual wage gap	−0.529 (0.389)	5898
[3]	Wage gap	−0.863* (0.448)	5898
	+ Employment of 25–49 year olds	0.737 (0.633)	5898
[4]	Outside wages only	−0.979* (0.551)	5898
[5]	Wage gap, inside wage corrected for teacher composition	−0.929*** (0.351)	5898
[6]	Conley standard errors (TTWA Level)	−0.895** (0.435)	5898
[7]	Without KS2	−1.197*** (0.454)	5898
School gaming			
[8]	Exclusions as dependent variable	0.124 (0.474)	60
[9]	Number of exams taken as dependent variable	−0.162*** (0.063)	5760

KS4 school performance is dependent variable unless stated otherwise. Controls in all regressions for Key Stage 2 (KS2), %Free School Means (FSM), %Male, %Severe Special Educational Needs (SEN) and Expenditure per pupil. Row [8] estimated at GOR level with GOR fixed effects. Standard errors clustered at TTWA level (of which there are 529 clusters) and bootstrapped with 1000 repetitions (unless stated otherwise). They are given in the parentheses. * significant at 10% level, ** 5% level, * 1% level.

each school's unique TTWA. We change this radius in 10 km steps from a minimum of 10 km to a maximum of 120 km. The estimated wage coefficient for each radius and the associated 95% confidence intervals are plotted in Fig. 2. This figure clearly shows the results are insensitive to the precise choices of the radius for distances between 20 and 60 km. Larger areas cannot really be considered to be a TTWA for a school and we also find no effect at the very small radius of 10 km. It is possible at this small radius wages are endogenous; we return to this below in Section 5.3.[28]

Third, outside employment prospects may matter as well as wages. At the very least, if employment falls, average wages rise due to composition effects. To check whether this impacts on our results we add the employment rates of 25–49 year old at the local authority level over the 5-year period for which the cohort is in school as an additional control. Row [3] shows that the coefficient on the wage gap falls a little but remains significant at the 10% level. The coefficient on the employment rate is insignificant.

Fourth, our model is driven by the difference between inside and outside wages. The inside wage at school level may be endogenous if schools try to circumvent wage setting. To test this we omit the regulated wage and estimate the effect of only the outside wage. The results in row [4] indicate that the coefficient on the outside wage is actually very little different from that on the wage gap in our baseline estimates in row [1], though inclusion of the regulated wage improves the precision of our estimates. This suggests that the average school was not able to the circumvent wage regulation.[29]

Fifth, we use a more sophisticated measure of outside wages that creates an area- and time-specific outside wage for teachers using the observed characteristics (age, gender, years of schooling, etc.) of teachers in a particular area-year cell (we do not observe these characteristics at the school level).[30] The results in Row [5] show that this has little effect on the estimated wage coefficient. Examination of the adjusted wage series shows that the difference in characteristics between teachers and those working in other sectors does not vary greatly over time in an area (available from authors). Thus the main cause of area-specific time-series changes in the wage gap is simply the growth in the non-manual wage in an area rather than changes in observables or the price of these observables over time. This supports our use of a measure that does not adjust for composition.

Sixth, there may be common unobserved shocks to wages at the local geographical level (the TTWA). To allow for this, we use spatially correlated standard errors as in Conley (1999). Row [6] shows the estimates remain significant at the 5% level.

Finally, wage changes in an area may lead to school composition changes, both at intake at age 11 and during the 5 years in the run-up to Key stage 4 exams if children change school between the ages of 11 and 16. We go some way to picking this up by controlling for KS2 and other characteristics of the school cohort who sit the KS4 exams. But there may remain unobservable time-varying changes in the school cohort which we cannot control for with school fixed effects (as they are not time varying) or may not control for with the cohort level time-varying measures of initial ability (KS2 mean) and other pupil characteristics. Estimates without controls for KS2 provide some indication of whether unobservable changes in ability might affect our results. In Row [7] of Table 3 we present results without controls for KS2. These are about 20% higher than our baseline estimate. This suggests that if an increase in wages is negatively correlated with changes in unobserved post-intake ability of the school population, our estimated effect may be a biased upwards. On the other hand, if changes in post-intake unobserved ability are positively correlated with shocks to wages, then our estimates will be biased towards zero. Arguments can be made for both a positive correlation (parents can buy more goods to complement schooling) and a negative one (parents who have an income shock substitute towards paid work and have less time to supervise their children).

4.3. Tests of the salience of our research design

Our argument is that pay regulation acts as a ceiling and we exploit this to identify the impact of pay on school productivity. However, we do not observe what the unregulated wage for teachers would be. While it is difficult to estimate the exact counterfactual wage for a teacher in the outside labour market (see Ma et al., 2009, for one approach) even without observing this counterfactual we should expect to find more effect where the ceiling is more likely to bite. This is in labour markets where outside wages are highest and where schools have least power over wage setting and conditions of employment.

To compare the effect of an outside wage shock across heterogeneous outside labour markets we estimate the response to an outside wage shock separately for schools in each of the three 'outside wage regions'. The results presented in Table 4 show a monotonic relationship between the wage gap and reduction in value added. Column [1] of Table 4 shows a negative interaction term for the highest wage region. Column [2] shows a positive interaction term for the lowest wage region. Column [3] presents estimates for each outside wage region separately. These confirm the results of the previous two columns: the

[28] This smaller coefficient is not due to the reduced sample size as the coefficient with the same set of schools as in the 10 km regression but with a TTWA radius of 30 km is −1.389 (s.e. = 0.597). In further analyses we weighted wages by the inverse of the distance from the school to each LA headquarter used in the construction of the wage. This did not materially alter the results. The results are also not sensitive to how we treat assign wages to schools that have no Local Authority whose headquarters lie within a 30 km radius (available from the authors).

[29] In Table 4 below we follow this up by examining those schools most likely to be affected by the regulation.

[30] This follows Propper and Van Reenen (2010) who use this approach to construct a wage which corrects for labour market composition appropriate to nurses. Construction details in Appendix B.

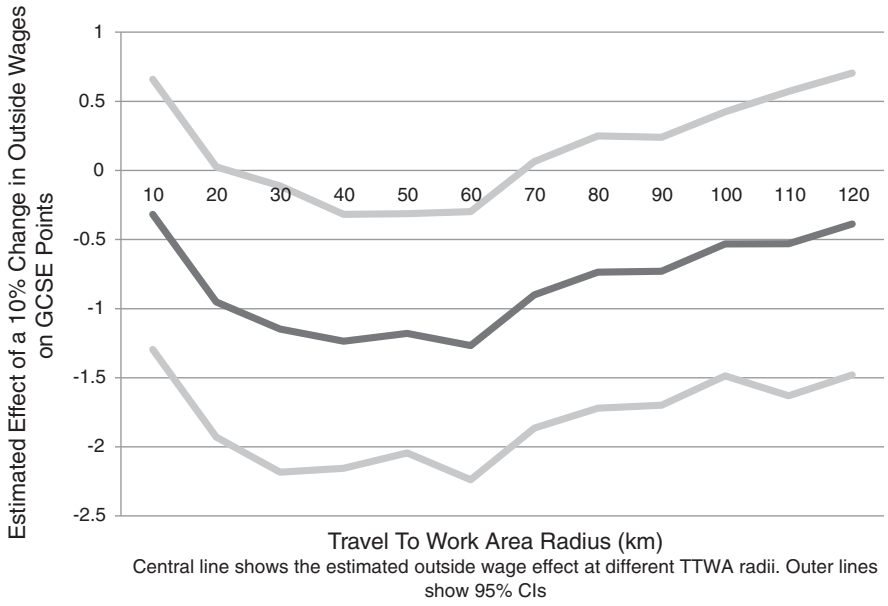

Fig. 2. Coefficient estimates for KS4 from wages estimated at different sizes of Travel to Work Area.

Table 4
Tests of salience of research design.

	Regional Heterogeneity			Excluding London	Only Schools with No Control over Wages: KS4	Only Schools with No Control over Wages: 5A*-C
	[1]	[2]	[3]	[4]	[6]	[7]
Wage gap	−0.752*	−1.213***		−1.127**	−1.372***	−0.321***
	(0.428)	(0.017)		(0.555)	(0.519)	(0.108)
HW*Wage gap	−0.850**		−1.407***			
	(0.345)		(0.488)			
MW*Wage gap			−1.051**			
			(0.445)			
LW*Wage gap		1.320***	0.130			
		(0.400)	(0.567)			
Controls	Yes	Yes	Yes	Yes	Yes	Yes
No. Schools	2938	2938	2938	2609	1825	1825
N	5976	5976	5976	5218	3650	3650

All regressions have 2 observations per school, with the school outcome in 2002 and 2008. Wage gap is the average TTWA wage over five years (the "Outside wage"), lagged by one year (i.e. 1997–2001 and 2002–2006), minus inside teacher wages lagged by one year (i.e. 2001 and 2006). Inside teacher wages vary at the teacher payband level. Controls in all regressions for Key Stage 2 (KS2), %Free School Means (FSM), %Male, %Severe Special Educational Needs (SEN) and Expenditure per pupil. The results are robust to alternative definitions of the wage regions. The exclusion of London excludes all schools in inner or outer London. Schools are defined as facing high local competition if more than 8 schools within a 10 km radius. Schools with no control over wages are 'Community' secondary schools. Standard errors robust and clustered at the TTWA level (of which there are 529 clusters), and are bootstrapped with 1000 repetitions. They are given in the parentheses.* indicates significant at 10% level, ** 5% level, * 1% level.

effect of pay is to reduce school productivity most where the pay regulation bites hardest and to not affect it where the wage gap is small.[31]

These results fit with the pattern in regional wage changes that were discussed in Section 3.4. While London and the South East may have the highest long run level of outside wages, our estimates recover a response to shocks to outside wages. These have been largest in the high 'outside wage' region but they also have arisen in several labour markets located in the middle 'outside wage' region. For example, of the LAs in the top quartile of highest wage growth in our period, 35% are in the middle 'outside wage' region. For these LAs our estimates of the counterfactual wage (what would be paid in the absence of regulation) is £1750 higher than the regulated wage.[32] Thus wage regulation bites in the middle, as well as the highest wage area, and we find a response to wages in both.[33] We also check that our results are not driven by London schools. Column [4] of Table 4 omits all London schools and shows are results are not 'a London effect'. The point estimate of a wage shock for such schools is around 30% higher, though the difference with the full sample is not statistically significant.

[31] Estimates for the 5 A*-C margin also show a similar pattern: the coefficients are −1.53 (0.66), −1.42 (0.64) and −0.62 (0.69) in the high, medium and low wage regions respectively.

[32] For method of estimation of the counterfactual wage see Appendix B.

[33] The tests in Table A4 show some association of observables with wage growth within the different wage growth regions. Given the patterns in the table, unobservables which are positively correlated with the observable covariates might bias in the within region estimates presented in section IV.D For example, if a rise in children with free school meals indicates the pupil body is more difficult to educate, then would give an upward bias to our results in high outside wage regions. If a fall in the number of pupils who have special needs indicates that the pupil body is easier to educate, this will bias our results for low wage regions downwards. However, provided the direction of bias is small (perhaps supported by the fact that controls for observed school level covariates have little effect on the estimates) this will not alter the overall pattern that the impact of wages is largest where the wage gap is lowest.

We would expect a larger effect for schools which have least power over their terms and conditions of employment. Other schools might try to circumvent the regulation in a way that would lead to a smaller impact of the wage gap for such schools. In England, secondary schools are classified into a number of types, the most common being Community Schools. These schools are not permitted to select pupils and LEAs have control over their curriculum and teacher wages. In the other types of state schools pupil selection is sometimes an option (for example, publicly run religious schools) and there is, in theory at least, more flexibility in terms of teacher wage setting. In columns [5] and [6] we present the estimates for Community Schools only. Column [5] is for KS4 results and column [6] for the 5A*-C proportion. The magnitude of the coefficient increases in each case by around 30% compared to the estimates for all schools. These results provide support for our argument: there is a stronger effect amongst schools with the least (no) power over their wage setting which is where the gap will bite hardest.[34]

4.4. School gaming

KS4 exams are high stake exams, not just for children, but also for schools. This may lead to school gaming and if this is associated with higher wage growth it could bias our results. By looking at both a measure of average performance (adjusted for intake) and performance on the key 5 A*-C metric, which matters most for lower ability students, we look at performance at different parts of the ability distribution. So if gaming only affects the performance of low or high ability students, our approach should deal with this.

But to further investigate this we first consider whether schools subject to wage shocks try to prevent children from sitting exams by excluding them. We can examine this only at regional (the 10 GORs) level due to lack of published data on exclusions at the school or LEA level.[35] The results of a regression of wage shocks on exclusions at the regional level are presented in Table 3, row [8]. This shows no relationship between the outside wage and the number of exclusions, suggesting schools do not react to wage shocks by baring pupils from exams. Second, it is possible that schools react to outside wage pressure by limiting the number of exams that pupils take in order to get better average performance. To examine this we re-estimate our baseline model using the average number of exams taken as the dependent variable. The results in row [9] show that schools do respond at this margin: a 10% increase in the outside wage causes schools to reduce the average number of exams taken by each pupil by just over 0.16. They may be doing this to hit the key 5 A*-C metric. However, as Table 2 shows, this strategy does not appear to prevent them from having lower performance on this metric. But it may mean that our results are under-estimates of the impact of the outside wage: schools subject to shocks may divert more of their effort to hitting the targets at the expenses of higher scores above the target.[36] We conclude that while wage shocks may induce schools to game, gaming does not drive our results. Schools subject to wage shocks do not exclude pupils to avoid poor performance and while they reduce the number of exams their pupils take, wage shocks still negatively affect performance at both the high end (students who take many exams) and at the lower end (those students aiming for the 5 A*-C minimum) of the ability distribution.

On the basis of this battery of tests, we conclude that our identification strategy is robust. School performance is decreased by positive shocks to wages in the local labour market, there is an effect for both high and low ability pupils, and the effect is stronger where the wage ceiling has more bite.

5. Mechanisms

Our argument is that shocks to outside wages can drive teacher effort (through an efficiency wage effort) and labour supply (the loss of good teachers) and that this lowers the quality of teaching. But it is possible that the results are not due to responses of teachers but are driven by responses of pupils and their parents to outside market conditions.

While we cannot rule this out completely, we provide descriptive (as it is mainly cross-sectional) evidence on this by examining a measure of teacher quality that should not be affected by pupil type, so shutting down a pupil effect; we directly examine the relationship between wages and teacher tenure to see if schools subject to wage shocks experience problems with teacher retention; and we examine whether the plausible responses of pupils to outside labour market conditions drive our results. Finally, we discuss evidence relevant to parental behaviour.

5.1. The effect of wage regulation on quality of teaching

One way to examine the effect between wages and quality of teaching would be to examine the qualifications of teachers. However, teacher qualifications are not likely to be a useful margin. First, research on teacher qualifications suggests there is little correlation between teacher qualifications and teacher effectiveness (e.g. Rockoff, 2004, Rivkin et al., 2005, Aaronson et al., 2007, for the USA and Slater et al., 2012, for England). Second, in the LFS data, most teachers are graduates and this figure does not vary systematically across regions.

Instead we examine a direct measure of the effectiveness of teaching in the school: the ratings the school received in their OFSTED inspection of school quality between 2003 and 2008. This measure should be less contaminated by unobservable (to us) attributes of the student body as the regulator ratings are based on in-depth inspections of the school carried out by experienced educators. School performance is rated on a number of dimensions, each using a four-point scale which ranges from 1 (outstanding) to 4 (inadequate).[37] In Table 5, column [1] we examine the relationship between overall performance of the school and outside wages and in column [2] we examine the relationship between the 'quality of teaching' score and outside wages.[38] We use the same lagged five-year average definition of outside wages and include pupil characteristics for the year of observation as in our baseline model. As there is only one observation per school we do not include school fixed effects but instead include LEA fixed effects.

The results show that a larger wage gap is associated with a poorer overall rating of the school (a positive coefficient indicates an increase in wages is associated with poorer performance). More importantly, it is also associated with poorer teaching quality. A 10% increase in the local labour market wage decreases the quality of teaching by 1.4 points.[39] This is a large effect: the mean teaching quality score is 2.6 so this is a fall in the teaching quality score of over 50% at the mean.

[34] An alternative interpretation is that estimates which include schools which have greater ability to circumvent the wage regulation would be more likely to suffer from measurement error, which would give downward bias to the estimates which included these schools. However, results which omit the inside wage (which is the source of the measurement error) have the same pattern: schools which are least able to circumvent wage regulation have a more negative wage effect.

[35] Data from the Department for Education, which provides exclusion data at GOR level only.

[36] We undertook further sensitivity tests, to which our results were robust. We excluded KS4 outliers; the coefficient (se) rose slightly to −1.192 (0.458). Our results are also robust to exclusion of small school cohorts (less than 30 students), so addressing potential problems in measurement of school outcomes (Kane and Staiger, 2002).

[37] There was a change in 2006 in the exact definition of the teaching quality component of the assessment from 'teaching' to 'effectiveness of teaching in meeting learners needs', so we demean the scores within year.

[38] The inside wages are subsumed into the LEA fixed effects

[39] Due to the change in the teaching quality variable in 2006, we also estimate the effect pre- and post-2006 separately. The coefficient (se) on the lagged average wage for 2003–2005 is 1.63 (0.331) and for 2006–2008 is 0.597 (0.327).

Table 5
Analysis of Pathways.

	REGULATOR ASSESSMENT		STAFF TENURE		YP WAGES	YP UNEMP
	[1]	[2]	[3]	[4]	[5]	[6]
Dependent var.:	Overall School Rating	Teaching Quality Rating	Proportion of Teachers <1 Year	Proportion of Teachers >10 Years	School KS4 Score	School KS4 Score
Wages	0.689**	1.459***	0.300***	−0.339**		
	(0.340)	(0.249)	(0.116)	(0.138)		
Local 16–25 Wages					−0.033	
					(0.027)	
Local 16–25 Unemployment						0.184
						(0.228)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	No	No	No	No	Yes	Yes
LEA dummies	Yes	Yes	Yes	Yes	No	No
School dummies	No	No	No	No	Yes	Yes
Years (dep var)	2003–2008	2003–2008	2010	2010	2004–2008	2004–2008
N	4567	3181	2680	2680	11,904	11,420

In Columns [1] and [2] dependent variable is OFSTED rating and the wage is "Wage gap", i.e. the average TTWA wage over five years (the "Outside wage"), lagged by one year, minus inside (teacher) wages lagged by one year. In Columns [3] and [4] the dependent variable is the proportion of teachers in a school with tenure <1 year, and >10 years respectively, and the wage is simply the "Outside Wage". Due to ASHE data limitations, outside wages are constructed from the LFS between 2005 and 2009, using full time wages of 22–60 year olds at Local Authority level. Controls variables from PLASC for 2008. In columns [5] and [6], the dependent variable is school performance, with wages and unemployment rates of 16–24 year olds at Local Authority level taken from LFS. Controls in all regressions for Key Stage 2 (KS2), %Free School Means (FSM), %Male, %Severe Special Educational Needs (SEN) and Expenditure per pupil. Robust standard errors in parentheses (bootstrapped and clustered at the TTWA level in columns 1 and 2). * indicates significant at 10% level, ** 5% level, * 1% level.

5.2. The effect of outside wages on teacher tenure

In our model, one effect of wage regulation is that teachers leave schools in high wage areas. This is likely to affect student performance through a variety of routes: time will need to be spent by the senior management team on recruitment rather than other activities, less experienced teachers may be less effective (Dolton and Newson, 2003, provide UK evidence on this) and there may be spillovers on the morale of the remaining teachers that may dampen effort (Ronfeldt et al., 2011).

To look at this channel (which is essentially selection) we examine the relationship between outside wages and teacher tenure in each school.[40] We exploit a recently released data set, which presently covers only 2010. We cannot, using these data, examine hires and separations, but we can examine the association between average tenure in schools in time bands and outside wages. We present the association between the proportion of the teachers who have very short tenure (less than a year in the school) and long tenure (over 10 years in the school) and lagged outside wages, averaged over five years to replicate the modelling of wages in our baseline specification.[41] We only have one observation per school so estimate Eq. (2) using LEA rather than school fixed effects, and report the results in Table 5, columns [3] and [4]. Column [3] presents estimates of wages on short tenure while column [4] examines long tenure.

The results show that where outside wages are high, schools have a higher proportion of teachers who have been in tenure less than one year and a lower proportion of teachers who have been in tenure for ten years only. The wage effect is little altered by controls for pupil type.[42] A £1000 increase in the outside wage results in a 0.25 percentage point increase in the proportion of teachers who have been in the school less than a year, and a 0.43 percentage point decrease in the proportion of teachers who have been in the school more than 10 years. While the magnitude of these effects is not large (the coefficients represent a 2% change for both short and long tenure), schools in high wage areas lose teachers faster and also have less experienced teachers.

5.3. A pupil or parental effect?

An alternative hypothesis is that our results are due to the responses of pupils and/or their parents to outside wages. The relationship we find could be driven by pupils responding to better labour market opportunities by decreasing their effort at school because they know there is an employment alternative. If this is the case, we would expect to find a negative relationship between school performance and higher outside wages and/or the demand for youth labour in the local labour market. To examine this we estimate the relationship between school performance and the demand for youth labour, as measured by local authority wages and, separately, the unemployment rate, of 16–25 year olds, lagged one year.[43] Regressions are at school level and include the same controls as our baseline specification and school fixed effects.

Table 5, column [5], presents the results for the association of school performance and youth wage rates. Column [6] presents the association with youth unemployment. Neither association is large or statistically significant. Further, for the negative relationship we find between outside wages and school performance to be driven by a pupil response, pupils would have to be responding negatively to positive outside wage or employment shocks. Whilst this is plausible, it seems equally plausible that at least some pupils respond to positive wage shocks by putting in more effort at school, on the grounds that if they get better exam grades they are more likely to get a (better) job. These plausibly heterogeneous responses do not

[40] Ma et al. (2009) show a negative cross-sectional association between teacher vacancies and local authority amenity adjusted wages for 2004–2007.

[41] We use wage data from the LFS, averaging wages at LA level between 2005 and 2009 (we use full time wages of all 22–61 year olds in order to preserve sample sizes). The wage for each school is constructed as the average of all LAs whose HQ lies within a 30 km radius of the school.

[42] Wage coefficients (se) without controls are 0.268 (0.040) and −0.45 (0.050) respectively. Results are robust to the precise definition of the TTWA over which wage is defined (results available from authors).

[43] We match Local Authority level NOMIS data into our PLASC dataset and include the lagged employment rate in our regressions. As the pupils who are at the margin between staying on and leaving are likely to be most affected by recent shocks, we use wages and unemployment rates lagged one year.

fit with our finding of a negative outside wage effect for both low ability students (those at the 5 A*-C margin) and all students (total exam points achieved).

An outside wage shock would also be a positive shock to parental income, which could result in worse performance if greater parental income means less supervision of children or more leisure time for children. While we cannot rule this out, the lack of significance of the full time male manual wages in the robustness checks in Section 4 brings into doubt whether the effect is working through parental income. If parental income was important, it is not clear why a parental income effect should operate only for parents in non-manual occupations. In addition, the large (though often correlational) literature shows a positive rather than a negative association between parental income and child attainment. It thus seems less likely that the negative relationship we find between outside wages and child attainment is driven by a parental effect.

School performance could affect outside wages, which would bias our results. The most obvious mechanism by which school performance may affect outside wages is through sorting: good schools attract high income parents to move into the area surrounding a school.[44] This would give a positive shock to the average outside wage and would bias our estimated coefficients upwards. However, the 30 km radius TTWA we use weakens this argument. If we had used the catchment area of a school to determine the outside wage this would be problematic, as parents try to buy houses in the catchment areas of 'good' schools. But much of that gaming is within area. Individuals are likely to choose areas based on their job and general lifestyle choice and then select their specific within-area locations based on the schools available. Fig. 2 shows a smaller relationship between outside wages and school performance at radii of 10 km and at 20 km. The TTWA radii at these distances give more weight to the local catchment area round each school, which may indicate endogeneity at this smaller spatial distance. Our analysis uses 30 km distance to avoid this problem.[45]

In summary, whilst these results are primarily descriptive as data limitations mean they rely on more restrictive assumptions than our main analyses, they suggest that the effect of shocks in outside wage on school performance is, at least in part, through lower teaching quality and labour supply and not from responses of parents and children to the local labour market. In fact, whilst pupils (and their parents) might respond, they probably do so in a way which biases our estimated coefficients towards zero.

6. Conclusions

This paper exploits the national regulation of teacher wages, national exams at entry into and exit from secondary (middle/high) schooling and a national school inspection system in England to estimate the effect of teacher pay on school productivity. We find that a larger gap between regulated pay and the outside labour market remuneration reduces school performance as measured by student performance in key exams and that the effect is larger where the ceiling imposed by regulation bites harder and for schools that have no control over pay and conditions at school level. At the average a 10% increase in the local labour market wage would result in an average increase of 2% in the scores attained in the high stake exams taken by pupils at the end of compulsory schooling in England. But the effect in areas or schools where the ceiling bites harder is around 30% higher.[46]

Lazear (2000) emphasises that incentives can affect performance through both effort and sorting. The national set up of the wage regulation in England means that both channels are likely to operate. Wage regulation which keeps teacher relative wages low in one (large) area of the country and high in other (large) areas will encourage both effort reduction and mobility of teachers to area where they get better relative remuneration for the same job. Data constraints mean that we cannot trace through all the pathways through which the pay effect operates but it seems likely that both channels operate. We have shown that school performance and direct measures of the quality, which are important to schools under the 'name and shame' rating system used at national level in England, are lower in schools where regulation bites harder. This may reflect reduced effort of the teachers in the schools but we also show that schools subject to high outside wages relative to regulated pay also have higher staff turnover, which may reflect movement of teachers away from these areas.

Our findings support the view that teacher pay is important for school performance. The recent focus of many governments has been on using pay for performance for teachers (e.g. Lavy, 2009). However, centralised pay setting affects teachers in many more countries than are using pay for performance in the classroom. Our findings suggest that policy effort could be usefully directed towards increasing flexibility in these centralised wage setting processes.

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Appendix A

Table A1
Data Sources

Data	Source	Years
School Value Added, KS4 and KS2 Grades, Case Mix Controls, School Type, 5A*-C %	PLASC	2002–2008
Outside Wages	ASHE	1997–2006
Exclusions	Dept. for Education	2002–2007
OFSTED	Dept. for Education	2003–2008
LEA 5 A*-C Proportion (1997)	Dept. for Education	1997
YP Wages	LFS	2004–2007
YP Unemployment	LFS	2004–2007
25–49 Unemployment	NOMIS	2003–2007
Inside Wages	Teacher Pay & Conditions Handbook	2001–2007
Outside Wages, Tenure Regressions	LFS	2005–2009
Teacher Tenure	School Workforce Census	2010
No. Exams Taken	NPD	2002–2007

[44] English schools have pre-set catchment areas which define pupil eligibility to attend the school.

[45] In Fig. 2 the effect at 30 km is slightly larger than from our main regressions (−0.980). In the main regressions we match schools to the nearest LA when there is no LA within the 30 km radius. For Fig. 2 schools with no LAs within the given radius are dropped.

[46] We undertook simple calculations of the potential gain of removal of wage regulation. These show a positive gain under a range of assumptions on key parameters. Results available from the authors.

Table A2
Outside Wage Regions

Panel A: High, Medium and Low Outside Wage Regions

Government Office Region (GOR)	Average Wage, 2006 (£)	Wage Region
North East	29,092	Low
Yorkshire & the Humber	30,043	Low
West Midlands	30,724	Low
East Midlands	30,809	Low
North West	30,941	Medium
South West	31,330	Medium
East	34,105	Medium
South East	37,223	High
Inner London	37,248	High
Outer London	49,484	High

Panel B: Nominal Total Wage Increases by Outside Wage Region (£)

Growth Period	HW region	MW Region	LW Region
1997–2001	5220	3569	2327
	(3568)	(2298)	(2864)
2002–2006	4381	3510	3716
	(4420)	(1980)	(2154)
1997–2006	12,208	9490	8399
	(4711)	(2849)	(2588)

Source: ASHE. Standard deviations of wage growth are given in the parentheses. The top two rows of.
Panel B do not sum to the bottom row due to wage growth between 2001 and 2002.

Table A3
Descriptive Statistics

Variable		Mean	Standard Deviation	Minimum	Maximum	N
Variables Used in Main Regressions						
Key Stage 4	Overall	44.08	10.18	14.86	99.01	5898
	Between		9.120	18.87	85.47	
	Within		4.530	25.52	62.65	
Key Stage 2	Overall	26.68	1.930	19.69	33.42	5898
	Between		1.700	21.26	32.73	
	Within		0.920	24.23	29.13	
Five A*-C %	Overall	0.565	0.192	0.048	1	5898
	Between		0.175	0.126	1	
	Within		0.079	0.248	0.881	
Average Outside Wage (5 Years, log)	Overall	7.134	0.161	6.651	7.615	5898
	Between		0.113	6.845	7.489	
	Within		0.115	6.940	7.328	
Inside Wages (log)	Overall	6.430	0.083	6.341	6.658	5898
	Between		0.034	6.413	6.548	
	Within		0.075	6.319	6.540	
Wage gap (log)	Overall	0.704	0.104	0.310	1.103	5898
	Between		0.095	0.432	1.046	
	Within		0.042	0.582	0.826	
Expenditure Per Pupil (EPP)	Overall	4.102	1.059	1.375	20.75	5898
	Between		0.639	2.686	12.21	
	Within		0.844	−4.442	12.65	
Free School Meals (FSM) %	Overall	0.132	0.126	0	0.89	5898
	Between		0.123	0	0.875	
	Within		0.029	−0.052	0.317	
Male %	Overall	0.506	0.189	0	1	5898
	Between		0.186	0	1	
	Within		0.030	0.271	0.740	
Special Educational Needs (SEN) %	Overall	0.023	0.020	0	0.394	5898
	Between		0.018	0	0.307	
	Within		0.010	−0.080	0.127	
Variables Used in Robustness Checks						
Average	Overall	9.132	1.071	1	15.04	5760
Number of Exams	Between		0.896	5.252	12.89	
taken	Within		0.587	4.399	13.87	
LA 16-25 Unemployment	Overall	0.078	0.021	0	0.207	14,825
	Between		0.014	0.025	0.129	
	Within		0.015	0.006	0.169	
LA 16-25 Wages	Overall	17,738	2809	9240	30,000	15,445
	Between		2215	13,218	22,265	
	Within		1729	10,680	26,180	

(continued on next page)

Table A3 (*continued*)

Variable		Mean	Standard Deviation	Minimum	Maximum	N
LA 25-49 Employment	Overall	0.810	0.060	0.555	0.947	39,224
	Between		0.052	0.628	0.901	
	Within		0.029	0.696	0.910	
OFSTED Overall School Rating	Overall	2.646	0.876	1	4	4919
	Between		0.781	1	4	
	Within		0.500	0.851	4.146	
OFSTED Teaching Quality Rating	Overall	2.663	0.782	1	4	3397
	Between		0.734	1	4	
	Within		0.383	1.597	3.996	
Variables with no within school variation						
LFS Av. Wage (05–09)	Overall	29,338	4396	21,369	53,368	3089
Tenure <1 yr	Overall	0.113	0.083	0	1	2646
Tenure >10 yrs	Overall	0.217	0.111	0	0.792	2646

Table A4
Test of Association between wage growth and student characteristics

	Full sample		High Outside Wage Region		Medium Outside Wage Region		Low Outside Wage Region	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
KS2	0.000	−0.001	0.000	−0.001	0.001	−0.002	−0.001	−0.004**
FSM	0.007	−0.010	0.030**	0.037*	−0.012	−0.032	−0.012	−0.014
Male	0.002	0.003	−0.003	0.005	0.003	−0.017	0.004	−0.005
SEN	−0.000	−0.033	0.026	0.049	0.015	−0.080	−0.058**	−0.154**
F Stat	0.347	0.559	2.583**	1.666	0.518	1.068	2.154*	4.355***
	(0.846)	(0.692)	(0.035)	(0.155)	(0.723)	(0.371)	(0.072)	(0.002)
School FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	(3051)	(2987)	(1159)	(1130)	(1105)	(1085)	(787)	(772)
Years	2002–2007	2002, 2007	2002–2007	2002, 2007	2002–2007	2002, 2007	2002–2007	2002, 2007
N	18,164	5974	6887	2260	6586	2170	4691	1544

Regressions at school level. All regressions contain year dummies. The F statistic is given for each regression, which jointly tests the significance of the regressors in the regression of one year lagged log outside wage on Key Stage 2 (KS2), % eligible for free school meals (FSM), %Male, %Pupils with Special Educational Needs (SEN). P values for the F stats in parentheses. Wage regions are determined based on growth rates of outside wages from 2002 to 2007. The HW region consists of the North West, Yorkshire, Inner London and Outer London. The MW wage region is West Midlands, South East and East Midlands. The LW region is South West. North East and East. * indicates significant at 10% level, ** at 5% level, *** at 1% level.

Table A5
Test of Association between Baseline covariates and subsequent wage growth
Dependent variable: 5 year outside wage growth

	Overall			HW Region			MW Region			LW Region		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
F Stat	1.013			0.465			1.711			0.665		
	(0.403)			(0.761)			(0.167)			(0.620)		
Key Stage 4		0.000			0.001			0.002			0.010	
		(0.001)			(0.015)			(0.010)			(0.016)	
5 A*-C			−0.156			−0.439			−0.137			−0.164
			(0.149)			(0.313)			(0.273)			(0.156)
LEA FE (148)	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Region FE (10)	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
N	148	149	260	50	50	94	47	48	78	51	51	88

Regressions at LEA level. The first column for each set of regression gives the F statistic which jointly tests the significance of the five baseline controls in a regression of outside wage growth between 2002 and 2006 on %on free school means (FSM), %Male, %Severe special educational needs (SEN) and Expenditure per pupil in 2002. In the second column of each set, wage growth is regressed on KS4 scores in 2002. In the third column for each set there are two observations per LEA, and wage growth (1997–2001 and 2002–2006) is regressed on baseline 5 A*-C grades (1997 and 2002), with LEA fixed effects. P values for robust standard errors in parentheses.* significant at 10% level, ** 5% level, * 1% level.

Appendix B. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jpubeco.2015.12.004.

References

Aaronson, D., Barrow, L., Sander, W., 2007. "Teachers and student achievement in the Chicago public high schools". J. Labor Econ. 25 (1), 95–135.

Akerlof, G., 1982. "Labor contracts as partial gift exchange". Q. J. Econ. 97, 543–569.

Barr, A., Zeitlin, A., 2010. "Dictator Games in the lab and in Nature: External Validity Tested and Investigated in Ugandan Primary Schools" CSAE WPS/2010-11.

Barrow, L., Rouse, C.E., 2005. "Causality, Causality, Causality: The View of Education Inputs and Outputs from Economics", WP-05-15. Federal Reserve Bank of Chicago.

Benton, T., Hutchison, D., Schagen, I., Scott, E., 2003. Study of the Performance of Maintained Secondary Schools in England. Report for the National Audit Office. National Foundation for Educational Research, London.

Bulman, J., 2002. Patterns of pay: results of the 2002 new earnings survey. Labor Market Trends 110 (December), 643–655.

Cappelli, P., Chauvin, K., 1991. "An inter-plant test of efficiency wage arguments". Q. J. Econ. 103, 769–787.

Conley, T.G., 1999. "GMM estimation with cross sectional dependence". J. Econ. 92 (1), 1–45.

Dolton, P., 1990. "The economics of UK teacher supply: the graduate's decision". Econ. J. 100 (400), 91–104.

Dolton, P., 2006. "Teacher Supply". In: Hanushek, E., Welch, F. (Eds.), The Handbook of Education Economics North Holland: Amsterdam.
Dolton, P., Marcenaro-Gutierrez, O.D., 2011. "If you pay peanuts do you get monkeys? A cross-country analysis of teacher pay and pupil performance". Econ. Policy 26 (65), 5–55.
Dolton, P., Newson, D., 2003. "The relationship between teacher turnover and pupil performance". Lond. Rev. Educ.
Dolton, P., van der Klaauw, W., 1995. "Leaving teaching in the UK: a duration analysis". Econ. J. 105 (429), 431–444.
Duncombe, W., Yinger, J., 1998. "School finance reform: aid formulas and equity objectives". Natl. Tax J. 512, 39–62.
Duncombe, W., Yinger, J., 2011. Making do: state constraints and local responses in California's education finance system. Int. Tax Public Financ. 18 (3), 337–368 June 2011.
Eom, T.H., Duncombe, W., Yinger, J., 2007. "The Unintended Consequences of Property Tax Relief: New York State's STAR Program". Syracuse University Working Paper.
Figlio, D.N., 1997. Teacher salaries and teacher quality. Econ. Lett. 55 (2), 267–271.
Galgóczi, B., Glassner, V., 2008. "Comparative Study of Teachers' pay in Europe". European Commission ETUI-REHS Research Department, Brussels.
Gordon, I.R., Monastiriotis, V., 2007. "Education, location, education: a spatial analysis of secondary school exam results in England". Urban Stud. 44, 1203–1228.
Hall, E., Propper, C., van Reenen, J., 2008. "Can Pay Regulation Kill? The Impact of Labor Markets and Skills on Hospital Productivity". Working Paper no. 13776. NBER, Cambridge, MA.
Hanushek, E., 1997. Assessing the effects of school resources on student performance: an update. Educ. Eva. Policy Anal. 19 (2), 141–161.
Hanushek, E., 2003. The failure of input-based schooling policies. Econ. J. 113 (485), F64–F98.
Hanushek, E.A., Rivkin, S.G., 2006. Chapter 18 Teacher Quality. In: Hanushek, E., Welch, F. (Eds.), Handbook of the Economics of Education 2, 1051–1078 (Elsevier).
Hendricks, M., 2014. "Does it pay to pay teachers more? Evidence from Texas". J. Public Econ. 109, 50–63 January 2014.
Hoxby, C., 2001. "All school finance equalizations are not created equal". Q. J. Econ. 116 (4), 1189–1231.
Kane, T., Staiger, D., 2002. "The promise and pitfalls of school accountability measures". J. Econ. Perspect. 16 (4), 91–114.
Leigh, A., 2012. "Teacher pay and teacher aptitude". Econ. Educ. Rev. 31 (2012), 41–53.
Lavy, V., 2009. Performance pay and teachers effort, productivity and grading ethics. Am. Econ. Rev. 99 (5), 1979–2021 (43).
Lazear, E., 2000. "Performance pay and productivity". Am. Econ. Rev. 90 (5), 1346–1361.
Loeb, S., Page, M., 2000. "Examining the link between teacher wages and student outcomes: the importance of alternative labor market opportunities and non-pecuniary variation". Rev. Econ. Stat. 82 (3).
Lovenheim, M.F., 2009. "The effect of teachers' unions on education production: evidence from union election certifications in three Midwestern states". J. Labor Econ. 27 (4), 525–587.
Ma, A., Battu, H., Elliott, R., 2009. "Local Pay Differences and Vacancy Rates for School Teachers in England and Wales: Regional Differences in Teacher's Rates of pay and Teacher Vacancy Rates". University of Aberdeen HERU Working Paper.
Mas, A., 2006. "Pay, reference points and police performance". Q. J. Econ. 121 (3), 783–821.
Murnane, R.J., Olsen, R.J., 1990. "The effects of salaries and opportunity costs on length of stay in teaching: evidence from North Carolina". J. Hum. Resour. 25 (1), 106–124.
Nickell, S., Quintini, G., 2002. "The consequences of the decline in public sector pay in Britain: a little bit of evidence". Econ. J. 112, F107–F118.
Ondrich, Y., Pas, E., Yinger, J., 2008. "The Determinants of Teacher Attrition in Upstate New York". Public Finance Review 36, pp. 112–144 (January 2008).
Propper, C., van Reenen, J., 2010. "Can pay regulation kill? Panel data evidence on the effect of labor markets on hospital performance". J. Polit. Econ. 118 (2).
Rivkin, S., Hanushek, E., Kain, J., 2005. "Teachers, schools, and academic achievement". Econometrica 73, 417–458.
Rockoff, J., 2004. "The impact of individual teachers on student achievement: evidence from panel data". Am. Econ. Rev. 94, 247–252.
Ronfeldt, M., Lankford, H., Loeb, S., Wyckoff, J., 2011. "How Teacher Turnover Harms Student Achievement". NBER Working Paper 17176.
Shapiro, C., Stiglitz, J., 1984. "Equilibrium unemployment as a worker discipline device". Am. Econ. Rev. 74 (June), 433–444.
Sibieta, L., 2015. The Distribution of School Funding and Inputs in England: 1993–2013. Insitute for Fiscal Studies Working Paper W15/10.
Slater, H., Davies, N., Burgess, S., 2012. "Do teachers matter? Measuring the variation in teacher effectiveness in England". Oxf. Bull. Econ. Stat. 74, 629–645.
Weiss, A., 1980. Job queues and layoffs in labor markets with flexible wages. J. Polit. Econ. 88 (3), 526–538.
Woessmann, L., 2011. "Cross-country evidence on teacher performance pay". Econ. Educ. Rev. 30 (3), 404–418 (June 2011).
Zabalza, A., Turnbull, P., Williams, G., 1979. "The Economics of Teacher Supply". Cambridge University Press, Cambridge.