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No. 3776

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ISSN 0265-8003

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Discussion Paper No. 3776
February 2003

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CEPR Discussion Paper No. 3776

February 2003

ABSTRACT

The Impact of School Inputs on Student Performance: An Empirical Study of Private Schools in the UK*

In this article, we report the results of an empirical study of the impact of school inputs on pupils' performance in private (independent) schools in the United Kingdom. We use a new school-level panel dataset constructed from information provided by the Independent Schools Information Service (ISIS). We show a consistent negative relationship between the pupil-teacher ratio at a school and the average examination results at that school. Our estimates indicate that the relationship persists even when we are estimating 'added-value' models conditional on previous exam results. The results are noteworthy in comparison with studies for the state sector, relatively few of which have found a consistent and significant effect.

JEL Classification: I20
Keywords: exam performance, private schools, school resources and teacher-pupil ratio

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*Our thanks to Cecilia Rouse and other participants at the conference held at Princeton University in honor of Orley Ashenfelter for helpful comments. Also, our thanks to seminar participants at Oxford for comments and to Donald Hay for invaluable help on this project.

Submitted 27 January 2003

In this article, we report the results of an empirical study on the impact of school inputs on pupils' performance in private (independent) schools in the United Kingdom. We use a new dataset constructed from information provided by the Independent Schools Information Service (ISIS). This is a school-level panel dataset for the years 1988-1994 and includes resource information, examination results, and fees from UK private schools.

The question of whether school resources matter for student achievement has been debated for at least 30 years, primarily with data from state schools. The evidence in the US and the UK has been mixed, with several recent UK studies finding no effects from the pupil-teacher ratio (see Bradley and Taylor (1998), Feinstein and Symons (1999) and Dearden, Ferri, and Meghir (2002)).

A particular advantage and distinguishing feature of our dataset is that it consists entirely of private schools. This is important for several reasons. First, resources vary widely between private schools – much more so than for state schools. It may therefore be easier to identify a relationship between resources and pupil outcomes. Secondly, on average, private schools have a lower pupil-teacher ratio than state schools, which might also lead to different effects. Finally, some authors have suggested that teaching may be organized differently in private schools than in state schools.[1] Different resource utilization may lead to different resource effects. Thus, a natural question is whether a stronger relationship can be found between school resources and student outcomes in the private sector than has been found in the state sector.

We proceed as follows. In Section 1 we present a brief overview of the literature. In Section 2 we provide an empirical framework for the analysis of

[1] See Dearden, Ferri, and Meghir (2002), p. 9.

resources in private schools. In Section 3 we describe the data and summary statistics. In Section 4 we present and interpret the results of our estimates. In Section 5 we look at differences between resource effects in girls' schools and boys' schools, and in section 6 we conclude our analysis.

1. Resource Effects on Performance: Recent Studies

As we are interested in possible differences between previous work that has used data primarily collected from state schools and our study using data for private schools, we begin by describing the results of recent studies. The data that are most similar to ours are used in a study by Bradley and Taylor (1998). Using UK school-level data from the School Performance Tables for the years 1992 and 1996, Bradley and Taylor (1998) find that the level of the pupil-teacher ratio has no effect on exam performance, although they find a significant but very small effect when they look at the change in the pupil-teacher ratio between 1992 and 1996 and the change in exam performance.

Several papers that have looked directly at the impact of changes in the pupil-teacher ratio on academic achievement in secondary schools have been based on data from the National Childhood Development Survey (NCDS), which follows a cohort of individuals born in a week of 1958. Dearden, Ferri, and Meghir (2002) and Feinstein and Symons (1999) find that the pupil-teacher ratio has no impact on educational qualifications. The majority of individuals in this sample attend state schools: only 6% are in the private sector. In other work using NCDS data, Dustmann, Rajah, and Soest (2002) find that class size impacts the decision of whether or not to stay on at school, and through this mechanism, affects wages. Thus, UK studies have not found consistent relationships at the secondary level.[2]

[2] Using school-level data from the Department for Education and Skills, Gibbons (2002) finds that for

In the US, many studies have addressed the question of whether school resources affect performance. These studies have been analyzed as a whole in a series of influential summaries by Eric Hanushek (1986, 1989, 1996a, 1996b, 1997, 1998). Based on these studies, Hanushek argues "There is no strong or consistent relationship between school inputs and student performance."[3] Recently, this conclusion has been called into question by a new metastudy by Krueger (2000), and research using the results of the The Tennesse Student/Teacher Achievement Ratio experiment (project STAR) (see Mosteller (1995), Krueger (1999), and Krueger and Whitmore (2001)). There are also several new papers using instrumental variables on data from various countries, with varying results (see Akerhielm (1995), Angrist and Lavy (1999), Sander (1999), Hoxby (2000), Boozer and Rouse (2001), and Asadullah (2002).[4] These studies have all taken the bulk of their data from the state sector.

2. An Empirical Framework for the Analysis of Resources in Private Schools

We wish to estimate an educational production function at school level, in which the school's output, as measured by the pupils' performance in national examinations at ages 16 and 18, is determined by the resource inputs of the school (and in particular the pupil-teacher ratio). Since pupils' performance depends also on other variables for which we cannot fully control (such as their own ability, and support provided by parents) but which may be associated with the variation in inputs between and within schools, we have a potential endogeneity problem.

The endogeneity of school inputs is well-recognised in other recent studies, but the nature of the problem depends on the sample of schools. Hoxby (2000), for US

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primary schools, an extra qualified teacher for each 100 pupils leads to a 2.6 percentage point improvement in success rates.

[3] Hanushek, 1997, p. 148.

[4] For a thorough review of the current literature in both the US and the UK along with a good discussion of technical issues, please see Vignoles et. al., (2001). Other good literature surveys include Wößmann (2002), and the meta-studies of Hanushek (1997) and Krueger (2000).

public (state) schools, emphasizes that parents contribute directly to children's education, and that those who contribute more also choose to live in school districts with lower pupil-teacher ratios. For UK state schools, Dearden, Ferri and Meghir (2001) note that school resources are in part determined by educational policy choices intended to improve outcomes in socially-deprived areas. To establish the endogeneity issues arising in our dataset, we describe in the next section how resources are determined in UK private schools.

2.1 Determination of Resources in UK Independent Schools

Independent schools are almost all non-profit-making, with Charitable Status. We can model the market for private education as demand-led: if there is a group of parents of sufficient size wishing to purchase private education with particular characteristics, a school will enter the market to supply what they want, at cost.

Assume that a family desires good exam results, and that these depend positively upon the ability of the child, the resource inputs of the school, and also on the peer group – particularly the ability of other children in the school. If peer group effects matter, then each family prefers a school that excludes children of significantly lower ability than its own child. We would expect to see sorting by ability, with each school setting an entrance examination and accepting only those who reach its own ability threshold. Since higher ability children will apply to schools with higher thresholds, this will lead to a relatively narrow distribution of ability within schools. Sorting of this type is exactly what we see in the UK private education market. There is a hierarchy of schools with more or less stringent entry requirements. For example, many of the more prestigious schools use a standardised examination known as "Common Entrance" for entry at age 13, but schools adopt different pass marks.

In addition to the ability of the child, the family's educational choice depends critically on income. Everything else equal, higher income families will desire a higher level of resources. Resource levels, and hence fees, vary widely in the private schools sector. For example, pupil-teacher ratios vary between 7.9 at the 10th percentile and 14.2 at the 90th percentile, with correspondingly large differences in fees.[5]

We can therefore think of our sample of schools as differing from each other along two dimensions: the ability level of the pupils, and the level of educational inputs. Since we do not observe the ability level (although we can control for some pupil characteristics that are related to ability) we have a potential problem of bias. But to the extent that, at any given ability level, schools vary widely in resources because of variations in parental income and preferences, we should nevertheless be able to identify resource effects.

2.2 The Implications of the Endogeneity of Resources

Our results will be biased if school resources are related to unobservables such as the ability of the child or educational support provided by the family. Since parents with higher incomes will send their children to schools with better resources, a bias would be introduced if children's ability, or educability, were correlated with parental income. This is relatively unimportant in our dataset, however, since *all* families that send their children to private schools are in the upper strata of the income distribution. Since private education is very costly, it is evident that all these families care about education, so a bias arising from differences in parental attitudes and support is similarly unlikely.

An important source of bias is the parents' choice of school, which as discussed above, depends on both the child's ability and parental income. The

[5] In a sub-sample consisting of only secondary schools, the pupil-teacher ratio is 7.6 at the 10th percentile and 12.6 at the 90th percentile.

direction of this bias depends on whether a family with a high-ability child wants a school with higher or lower resource inputs than an otherwise identical family with lower ability child. We can identify three distinct effects.[6] First, a high-ability child will obtain good examination results anyway. Second, a high-ability child has access to schools where other children are of high ability, which helps to improve results. Both of these effects will lead the parents of high ability children to choose lower educational inputs. Third, the return to educational inputs may differ according to the child's ability. It is certainly possible that the return to lowering the pupil-teacher ratio increases with ability.[7] However, some authors have suggested that the return to a low pupil-teacher ratio is higher for disadvantaged students. Lazear (2001) suggests, for example, that small classes are more helpful to disadvantaged students: evidence is provided by Angrist and Lavy (1999) and Krueger and Whitmore (1999). In UK state schools where the ability range within the school is wide, it is common to separate pupils into classes by ability for subjects such as mathematics, with smaller classes for lower ability pupils.[8] If we accept this evidence, we can conclude that all three effects act in the same direction, to produce a negative relationship between school resources and pupil ability. But since the evidence is not extensive, there remains a possibility of a bias in the opposite direction.

In our regressions we address the possibility of a bias arising from any systematic relationship between schools' resources and pupils' ability in three ways. First, we include the pupil characteristics that are present in the school survey data. Secondly, in the model for results at age 18, we control for the results of the same

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[6] These can be derived from a formal model of school choice.

[7] Support for this proposition may be found in the tutorial system of Oxford and Cambridge.

[8] Some additional support for this argument is provided by a particular group of schools in our dataset, belonging to the Girls' Day School Trust (GDST). GDST schools are well-known to have stringent entry requirements, accepting only pupils of the highest ability, but they have high pupil-teacher ratios (14.3 (top 10%) during the time of our sample), low fees, and very good examination results.

cohort of pupils in exams taken two years earlier. Finally, we include school fixed-effects. None of these are perfect solutions. Results from regressions that include prior exam performance must be interpreted as value-added results, as previous exam performance will have been influenced by school resources in earlier years. Including school fixed-effects will eliminate the variation in the pupil-teacher ratio between schools and will likely make it more difficult to find any effects.

2.3 Other Sources of Bias

A further source of potential bias in the estimates of the coefficient on the pupil-teacher ratio is omitted resource variables. For example, schools with a low pupil-teacher ratio may also be inclined to hire better-quality teachers. While we have some controls for teacher quality (the percentage of teachers who are graduates), these are imperfect. Hence, it may not be pupil-teacher ratios that are driving different exam results between schools, but better quality teachers. In this case, omitted resource variables would be working to overstate the returns to decreasing the pupil-teacher ratio. On the other hand, a school with low pupil-teacher ratios may be able to hire better quality staff because teachers prefer smaller classes, in which case it may be legitimate to attribute the effect to the pupil-teacher ratio.

Ideally, we would like to have class sizes for the older pupils who are studying for national examinations, rather than school-wide pupil-teacher ratios. As discussed earlier, selection policies in private schools lead to a narrow ability range, so we do not have the problem that within the schools more able pupils are taught in larger classes. However, class sizes do differ substantially by age, usually decreasing through the age range after a maximum in the middle of the primary years. Thus school-wide pupil-teacher ratios will be an imperfect measure of class sizes at the ages we are interested in, particularly because the schools differ widely in the age distribution of their pupils. To reduce this problem, we focus on a sub-sample of schools with secondary age pupils only.

Since we have a panel dataset, we can exploit the within-school variation of the pupil-teacher ratio. However, it is unlikely that the variation in the numbers of pupils and teachers from year to year is random, and this could introduce a bias in the estimate of the return; we therefore need to explore the reasons for changing numbers.

An important reason for pupil numbers to change is the decisions of pupils and parents about whether to remain in the same school for their sixth-form years (ages 17 and 18). Compulsory education ends at age 16. Some pupils leave education at this stage and others move to different schools. The number of sixth-form pupils may therefore be quite variable, and the school may not want to hire or fire teachers in response to such short-term fluctuations. Furthermore, it is unlikely to respond to a temporary fall in the size of the sixth-form by moving resources towards younger pupils, both because many teachers regard sixth-form teaching as the more attractive part of the job, and because it wishes to obtain good results at age 18 to attract future sixth-form pupils. Hence, changes in school-wide pupil-teacher ratios may have a substantial effect on sixth-form class sizes and thereby results at age 18. If this hypothesis is correct, we are likely to see much more effect of within-school variation of pupil-teacher ratios on results at age 18 than at age 16.

Omitted variable bias may be a problem, however. If the pupil-teacher ratio is increasing because teachers are leaving faster than students, this could be a sign that there is something "wrong" with the school. We are able to capture this partially by controlling for teacher turnover, but we cannot control for other sorts of variation. For example, if "good" teachers are leaving, this would bias our estimates toward finding resource effects. However, if the pupil-teacher ratio is decreasing because students are leaving faster than teachers, this could also be a sign that something is wrong; in this case, our estimates are understating resource effects. Below, we provide some evidence on what is driving year-to-year variations in the pupil-teacher ratio.

Finally, it may be that both examination results and pupil-teacher ratios are changing for a particular cohort of students because that cohort is particularly weak or strong. We are able to address this issue for results at age 18, by including the examination results of the same cohort two years earlier.

2.4 The Empirical Model

The considerations discussed above lead us to the following model specification. Let y_{st} represent examination results at age 18 in school *s* in year *t*, and z_{st} be examination results at age 16. Let R_{st} be a vector of resources supplied by the school, and P_{st} be a vector of pupil characteristics other than exam results. We suppose that results at age 18 are determined by an equation of the form

$$y_{st} = ?'R_{st} + ß'P_{st} + f\ z_{st-2} + s_s + d_t + e_{st} \qquad (1)$$

where d_t represents year-specific fixed-effects, s_s represents school-specific fixed-effects and e_{st} is an error term. Equation (1) is a "value-added" model; for examinations at age 16 we have no prior results, so our equation takes the form

$$z_{st} = ?'R_{st} + ß'P_{st} + s_s + d_t + e_{st} \qquad (2)$$

For comparison, we also estimate equation (1) without controlling for past results (setting $j = 0$).

Equations (1) and (2) allow us to estimate within-school effects of changes in resources on results at ages 18 and 16. We will use two other specifications for each of the two dependent variables. First, by restricting the school fixed-effect s_s to be zero, we obtain a model that captures both within-school and between-school effects. Secondly, in order to focus on between-school effects only, we average all the variables across years for each school to obtain a cross-sectional model. The pooled version of equation (1), for example, is

$$y_s = ?'R_s + \beta' P_s + f\, z_{s(-2)} + e_s \qquad (3)$$

(where the *z* variable is averaged over the years two years prior to those in the data period).

In the next section, we describe our data and explain the resources, pupil characteristics, and exam results that are included in our dataset.

3. Data and Background

Just under 7% of school pupils in England[9] attend independent (that is, private) schools, for which their parents pay fees. This figure has remained more or less constant since 1988 (the beginning of our data period). Since a higher proportion of independent school pupils stay on at school after compulsory education ends at age 16, the proportion of sixth-form students (17 and 18 year olds) who are in independent schools is somewhat higher. Independent schools are much more disparate than those in the state school system: they cater for a variety of different age groups; there are many single-sex schools, as well as mixed; there are boarding schools, day schools, and schools taking both day and boarding pupils. Many set entrance examinations to select pupils, but the selection criteria vary widely.

The data in this study were collected by the Independent Schools Information Service[10] (ISIS), in their annual census of accredited UK independent schools, for 1988-1994 (school years 1987/1988 – 1993/1994). We are interested only in schools taking pupils up to age 18, since we measure school performance by their success in examinations at ages 16 and 18. Some of these schools cater for the whole age range

[9] Source: DfEE *Statistics of Education: Schools in England*. England dominates our sample of schools, since it has the majority of the population, and the proportion attending private schools in other parts of the UK is much lower – about 2% in Wales, for example.
[10] ISIS is now ISCis: the Independent Schools Council information service.

from 5 to 18, but more than half of the schools in our dataset can be classified as "secondary" schools where pupils enter at age 11 and/or 13.

3.1 National Examinations

In the UK almost all students (95%) take national standardised examinations, known as GCSEs (General Certificate of Secondary Education), at the end of the final year of compulsory education at age 16. Around 30% of the age group take further nationally standardised academic qualifications, known as A-levels (General Certificate of Education: Advanced Level) at age 18, usually remaining in the same school for a further two years (in the sixth-form) in order to do so. We have measures of each school's performance both in GCSE and in A-level examinations.

Both GCSE and A-level performance are critical for a student's future career opportunities and university entry. Parents choose private rather than state education for different reasons, but the decisions of many are influenced by the belief that a private school, with smaller classes and better resources, will raise their child's examination performance. Although the advantages of smaller classes are a matter of debate in the academic literature, some parents apparently value them highly: the average annual fee for a child in a private secondary school is of the order of 40% of median disposable income for UK households (and 20% at the 90th percentile).

In GCSE examinations a separate grade is awarded in each subject entered. Good students, intending to stay on into post-compulsory education, typically take GCSEs in nine or ten subjects, and hope to achieve grades A to C. Our primary measure of a school's performance is the proportion of all GSCE entries for the school that were awarded an A grade[11]. After GCSEs, students enter the sixth form, where they specialise in three (or possibly four) subjects of their own choice, and take

[11] In 1994, the last year of our data, the A grade was subdivided into A and A* grades; we add these together to obtain our measure.

an A-level examination in each subject two years later. A-level passing grades are A to E. Again, we measure a school's performance by the proportion of entries that achieve A grades. We also look at other measures of A-level and GCSE performance to address possible selection issues.

A-levels have a long history, but GCSEs are relatively new: they replaced the previous system of examinations in 1988, the year before the first examination results in our dataset. Two distinct trends have been evident, and the subject of much national debate, since 1988: one is the steady improvement in performance at both GCSE and A-level, with higher proportions achieving good grades, and the second is the relative improvement of girls. Girls have achieved better results than boys at GCSE throughout the period, and the gap has widened; at A-level, boys' results were better in our data period, but girls improved faster, outperforming boys by the late 1990s.

3.2 School and Pupil Characteristics

The observable school characteristics that are of interest to us and are included in the survey are as follows. We have the total number of pupils each year, number of both full-time and part-time teaching staff, the proportion of these who are university or college graduates, and the number of teaching staff leaving and entering each year. From pupil and staff numbers we can calculate school-wide pupil-teacher ratios, but we have no information on actual class sizes, quality of teaching or teacher skill, which have been shown to be important in past work (Hanushek, (1992) Boozer and Rouse, (2001)). The survey contains yearly expenditure on upkeep and improvements to buildings and equipment, the proportion of students that are boarders, and the proportion whose parents live overseas. It records other variables, including the financial type of school (whether it has charitable, limited company, or proprietary status), pupils with parents in H.M. Forces, the proportion receiving financial contributions to fees from central or local government or the school itself, the date the school was founded, and information on fees.

The survey data needed to be cleaned. The primary problem is that zeros were entered in places where the school did not answer the question or if the question was not applicable. For example, if the school did not accept boarding students, a zero would be entered for the full boarding fee. In a small number of cases, primarily in 1988-1989, some schools did not answer important parts of the forms, such as number of students or number of teaching staff, and hence a zero would be recorded for these observations. If a zero occurred in either total number of students or in full time teaching staff, we dropped the observation. For observations used, the problem remains that in areas such as teaching staff changes, a zero may either indicate that there was either zero turnover, or that the survey question wasn't answered.[12] The A-level and GCSE results, which are separate from the survey, appear to be very clean and comprehensive.

Table 1 presents summary statistics for our full sample of 498 schools, and for the sub-sample of 267 secondary schools, which are defined as those that have fewer than 5% of pupils under age 11. A fuller definition of each variable is given in Appendix Table 1. The summary statistics reported are averages over the five years of the survey from 1990-1994 inclusive. As our value-added regressions use GCSE results from the two years prior (i.e. we control for the school's 1988 GCSE results in an observation using 1990 A-level results), for consistency and comparison we have not used observations on 1988 or 1989. Furthermore, the survey data appear to be better from 1990 onwards. Fees and capital spending have been adjusted for inflation.

For each variable we present the mean within each quartile of the distribution

[12] In the dataset of secondary schools used in the regressions, out of 1233 observations, zeros in staff turnover appeared 59 times. If turnover is averaged over two years (the variable used in the regressions), zeros occur only 4 times.

of A-level results. Note first the large disparity in A-level results by school. In the lowest quartile, the average proportion of A's at A-level is .096, whereas in the highest quartile, the average is .351. Furthermore, some variables exhibit strong positive correlations with A-level results: in particular the size of the school, the proportion of teachers who are graduates, capital spending, and fees. Most interestingly, the pupil-teacher ratio is also positively correlated with exam results. This is consistent with higher ability students being placed in schools with a high pupil-teacher ratio. There are strong negative correlations with turnover and founding date (schools founded earlier achieve better results).

3.2 Pupil-Teacher Ratios

The average level of the pupil-teacher ratio, which is 10 for secondary schools and 11 for the full sample, is notably lower (it is also more variable) than in the public (state) sector. Table 2 presents figures for comparison:

Table 2
Pupils per Teacher

	1988	1995	2000
Private (Independent) Schools	11.3	10.3	9.9
State Primary Schools	22	22.9	23.3
State Secondary Schools	15.4	16.5	17.2

Source: DfEE *Statistics of Education: Schools in England, 2000*

Note that that pupil-teacher ratios have fallen in independent schools, while rising in the state sector. The huge differences in pupil-teacher ratios are reflected in costs: total spending per pupil in state secondary schools in 1994/1995 was £2320. The average annual fee for older day pupils in the independent schools in our sample for 1993/1994 was £5004.

Table 1
Summary Statistics

Variable*	Secondary Schools					All Schools
	Quartiles of A's as a proportion of A-level entries					
	1st quart.	2nd quart.	3rd quart.	4th quart.	All	Full Sample
A's as a prop. of A-level entries	0.096 (0.030)	0.164 (0.016)	0.227 (0.018)	0.351 (0.081)	0.209 (0.104)	0.211 (0.102)
A's as a prop. of GCSE entries	0.181 (0.066)	0.277 (0.060)	0.352 (0.065)	0.516 (0.110)	0.331 (0.145)	0.350 (0.147)
no. of students	307.624 (107.439)	409.415 (149.666)	557.732 (178.167)	666.619 (232.465)	484.669 (219.963)	536.492 (250.942)
proportion boarding	0.492 (0.336)	0.475 (0.335)	0.489 (0.335)	0.381 (0.407)	0.460 (0.355)	0.312 (0.343)
proportion under 11	0.006 (0.007)	0.005 (0.005)	0.005 (0.009)	0.005 (0.007)	0.005 (0.007)	0.144 (0.163)
pupils per teacher	9.329 (1.815)	9.521 (1.884)	9.726 (1.687)	10.333 (2.024)	9.725 (1.883)	10.880 (2.337)
prop teachers who are grad.	0.872 (0.092)	0.903 (0.073)	0.928 (0.050)	0.936 (0.058)	0.910 (0.074)	0.852 (0.119)
turnover	0.115 (0.050)	0.104 (0.045)	0.085 (0.038)	0.085 (0.032)	0.097 (0.044)	0.099 (0.047)
day fees	1474.824 (374.635)	1576.701 (392.978)	1613.616 (437.107)	1527.035 (473.007)	1548.287 (420.552)	1349.264 (414.072)
boarding fees	2507.345 (302.427)	2532.335 (499.425)	2494.643 (507.315)	2789.229 (464.719)	2566.276 (462.900)	2455.621 (468.220)
capital spending per pupil	614.714 (466.920)	745.807 (444.934)	854.860 (822.392)	1069.269 (833.206)	820.233 (684.391)	613.243 (586.231)
prop. boys in 6th form	0.560 (0.395)	0.519 (0.329)	0.614 (0.343)	0.586 (0.428)	0.569 (0.375)	0.443 (0.407)
founding date	1838.940 (190.087)	1762.864 (189.051)	1758.106 (201.612)	1679.864 (223.937)	1760.242 (208.273)	1800.331 (182.545)
prop. new foreign pupils	0.034 (0.038)	0.030 (0.028)	0.020 (0.022)	0.012 (0.015)	0.024 (0.028)	0.018 (0.025)
no. of schools	67	67	67	66	267	498

*Please see Appendix Table 1 for variable construction

In order to examine year-to-year variation in the pupil-teacher ratio, we looked at whether teachers or pupils were driving year-to-year changes in the ratio within a school. Of the 387 increases in the pupil-teacher ratio, 213 (55%) were generated by a greater percentage change in teachers than in students. This could indicate that teachers are leaving faster than students and hence as discussed above, something is "wrong" with the school which could lead us to finding resource effects. However, of the 579 decreases in the pupil-teacher ratio, 325 (56%) were generated by a greater percentage change in students than in teachers. This could also indicate that something is "wrong" with the school, but in this case our findings would be biased downwards. Hence, an examination of the drivers of the pupil-teacher ratio does not lead us to conclusive evidence as to the direction of any biases.

4. Estimation and Results

In estimating the model outlined in section 2.4, the variables we use for R_{st} (measured resources for a particular school) are pupils per teacher, capital spending per pupil, number of students, proportion of teachers who are graduates, staff turnover, and proportion of male teachers.

The variables we use for P_{st} (pupil characteristics) are dummy variables for boys' and girls' schools,[13] proportion of boys in the sixth form, proportion boarding, and proportion of new foreign pupils. We expect such pupil characteristics to affect results primarily if these groups differ in ability, but they may also capture some characteristics of the school. Boarding schools, for example, may organise teaching differently, and may have higher unmeasured resources; but their pupils may differ, in particular because they have less parental input and assistance with their work. The gender of the pupils may be important as a pupil characteristic – as noted earlier, girls

[13] We define as a boys' school one that has fewer than 5% girls at age 14, and vice-versa for girls' schools. The remainder are mixed (the omitted category in the regressions).

do significantly better than boys in GCSE exams – but girls' schools may differ systematically from boys' (the boys' schools are the longer established schools in the sample, and traditions tend to be different). Schools that we define as "boys" may nevertheless have significant numbers of girls in the sixth form (we discuss this further in section 5 below), so we also include a variable for the proportion of boys in the sixth form to capture the actual proportion of male A-level candidates.

We take logs of variables that are not proportions or dummy variables (pupil-teacher ratio, school size and capital spending). The only exception is the turnover variable, for which, as noted above, some observations are zero.

GCSE's and A-levels are, in effect, two-year courses. That is, students study for two years to take these exams. For this reason, we average our independent variables over the current and previous year.[14] The one variable that we treat differently is capital spending. As this is a lumpy variable and there is no reason to suspect that year by year changes of spending on plant and equipment affect results, we average this variable over the seven years of the study for each school. Hence, we must exclude this variable when including school dummy variables.

Our empirical results are reported in Table 3 below. As discussed in section 2.3 we focus on the sub-sample of secondary schools, because for schools with a wider age-range some important variables will provide a less accurate measure of the resources devoted to secondary pupils. Regression results for the entire sample are reported in Appendix Table 2.

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[14] The boy and girl dummy variables are then defined as schools having less than 5% girls or boys, respectively, in both years.

Table 3
Impact of School and Student Characteristics on Academic Performance
Secondary Schools

	Between and Within School Effects			Between School Effects			Within School Effects		
	A's as a proportion of			A's as a proportion of			A's as a proportion of		
	A-level entries	A-level entries	GCSE entries	A-level entries	A-level entries	GCSE entries	A-level entries	A-level entries	GCSE entries
A's as a prop. Of GCSE entries	0.623 (0.018)			0.677 (0.030)			0.365 (0.038)		
ln pupils/ teacher	-0.076 (0.016)	-0.118 (0.022)	-0.103 (0.026)	-0.057 (0.024)	-0.133 (0.045)	-0.126 (0.059)	-0.091 (0.031)	-0.064 (0.033)	0.004 (0.032)
ln number of students	0.039 (0.006)	0.154 (0.007)	0.199 (0.008)	0.027 (0.008)	0.154 (0.012)	0.200 (0.017)	0.061 (0.038)	0.082 (0.039)	-0.052 (0.030)
ln capital spending per pupil	0.007 (0.003)	0.026 (0.005)	0.032 (0.005)	0.007 (0.004)	0.025 (0.009)	0.029 (0.011)			
prop. teachers who are graduates	-0.016 (0.029)	0.152 (0.037)	0.300 (0.046)	-0.039 (0.036)	0.156 (0.069)	0.291 (0.095)	0.008 (0.062)	0.018 (0.064)	0.111 (0.057)
turnover	0.061 (0.036)	0.014 (0.050)	-0.056 (0.062)	0.039 (0.063)	-0.074 (0.123)	-0.140 (0.157)	0.090 (0.048)	0.089 (0.049)	0.035 (0.045)
boys	-0.052 (0.040)	-0.205 (0.059)	-0.298 (0.074)	-0.003 (0.074)	-0.250 (0.110)	-0.470 (0.156)			
girls	0.003 (0.018)	0.104 (0.024)	0.174 (0.031)	0.006 (0.023)	0.092 (0.040)	0.135 (0.060)			
prop. boys in 6th form	-0.001 (0.016)	0.015 (0.025)		0.015 (0.028)	0.031 (0.048)		0.004 (0.041)	0.001 (0.044)	
prop. male teachers	0.045 (0.025)	0.019 (0.032)	-0.027 (0.039)	0.044 (0.034)	-0.017 (0.054)	-0.074 (0.085)			
prop male teachers x boys school	0.065 (0.045)	0.252 (0.067)	0.358 (0.084)	0.004 (0.083)	0.307 (0.124)	0.561 (0.178)			
prop male teachers x girls school	0.011 (0.046)	-0.027 (0.059)	-0.064 (0.068)	0.006 (0.057)	0.000 (0.098)	0.009 (0.129)			
proportion boarding	-0.038 (0.008)	-0.077 (0.013)	-0.079 (0.016)	-0.025 (0.013)	-0.067 (0.026)	-0.073 (0.034)	0.019 (0.047)	0.040 (0.047)	0.050 (0.041)
proportion new foreign pupils	0.127 (0.054)	-0.058 (0.071)	-0.302 (0.101)	0.166 (0.083)	-0.057 (0.138)	-0.377 (0.233)	-0.032 (0.109)	-0.050 (0.117)	0.026 (0.111)
year dummies F-statistics	4 (5.710)	4 (16.830)	4 (6.800)				4 (10.710)	4 (31.660)	4 (23.950)
school dummies F-statistic							266 35.86	266 38.02	266 667.29
no. of obs.	1233	1233	1233	267	267	267	1233	1233	1233
R-squared	0.768	0.493	0.562	0.877	0.546	0.600	0.876	0.859	0.927

Errors reported are robust (White) standard errors.
All regressions include a constant

The results indicate a negative relationship between the pupil-teacher ratio and examination results. In columns 1-3, we are estimating between-school and between-year effects of changes in resources ($s_s = 0$). A 1% decrease in the ratio of pupils to teachers leads to an increase of 0.076 in the proportion of A's at A-level, controlling for GCSE results. This corresponds to an elasticity of 0.36 at the mean.[15] Without controlling for GCSEs, we find bigger effects. A 1% decrease in the ratio of pupils to teachers leads to an increase of 0.12 in the percentage of A-grades at A-level (the elasticity is 0.56). The estimated effect of the pupil-teacher ratio on GCSE results is smaller: the improvement in the percentage is 0.10, but since the mean of GCSE results is higher, the elasticity is 0.33.

In columns 4-6 we are estimating the pooled model, which reflects the between-school effects of changes in resources. We find similar results in these regressions. When we look at within-school between-year effects in columns 7-9, we again find significant negative correlations when we control for prior exam results, but the correlations are no longer significant at the 5% level without these controls. The results are almost significant in the A-level regression results but are clearly insignificant in the GCSE regression results. This may be due to a combination of factors. First, as discussed in section 2.3, the variation of the within-school pupil-teacher ratio is likely to have a greater impact on sixth form class sizes. Secondly, schools may devote more resources to weaker cohorts. Hence, by not being able to measure actual class size and without good controls for ability, we may be underestimating resource effects.

Other effects are as follows. School size is highly significant in all the regressions that allow for between-school effects. Part of the explanation may be that schools that were effective and successful in the past have grown large. However there are good reasons to believe in returns to scale: larger schools are able to hire a wider range of specialist teachers, and to ensure that they are well-matched to pupils and subjects. Furthermore, teachers can specialize in subjects they prefer. Size

[15] The mean percentage of As is .209 (see Table 1). Equivalently, a reduction of class size from 10 (the mean) to 9 would lead to an improvement in our measure of A-level performance of 4%.

remains significant even in the within-school regressions for A-levels. A possible explanation is, again, that the size of the sixth-form is particularly variable, since it results from the choices of the pupils themselves, and when the sixth-form is larger the school is again able to match pupils and teachers more effectively.

Spending per pupil on plant and equipment positively impacts results in all regressions. The proportion of graduate teachers is not significant in any of the value-added regressions, but is significant in all other regressions except for the A-level regressions allowing only for within-school between-year effects. Teacher turnover does not display any consistently significant effects. Variation of the proportion of boarders does not affect within-school results, but the proportion boarding does appear to have a significant negative effect between schools. As mentioned previously, this may represent a genuine pupil characteristic or "ability" effect, since boarding pupils do not benefit from parental input to their studies.

The gender effects are interesting. None of the gender variables are significant in the value-added regressions: conditional on their performance at GCSE, boys and girls do equally well at A-level. But where we do not control for past performance, girls' schools do significantly better than mixed or boys' schools. While the coefficient on the dummy for boys' schools is significantly negative, we have also included an interaction term with the gender of staff, and boys appear to do better when taught by male teachers. Since the mean proportion of male teachers in boys' schools is 0.9, the combined effect is that a typical boys' school does not achieve significantly worse results than the mixed schools.

The better performance of girls' schools is particularly pronounced at GCSE, which is consistent with national trends as discussed in section 3.1. The effect at A-level is smaller, but still positive: it seems that, after controlling for resources, private girls' schools achieved better A-level results even at a time when boys were doing better than girls at this level nationally.

Although not reported, the estimated year dummies in all regressions where they are present reflect the national trend of improving results over the sample period, both at GCSE and at A-level.

4.1 Alternative specifications

As a robustness check, we estimated the equations with this year's and last year's resource variables entered separately, rather than averaging them over two years. These results are not presented, but the resource coefficients for the two years are very similar, and far from statistically significantly different from each other. We also estimated models in which we used the proportion of A's and B's as our measure of exam performance. These results are quite similar to our reported regressions in which the measure of exam performance is the proportion of A's only..

As one concern is that that the number of GCSE and A-level subjects taken can vary by individual, we also report regressions using the proportion of A's per candidate. In addition, as schools do not have to enter all students in the examinations (and some schools may choose to enter students of different ages for some examinations) we report regressions using the proportion of A's per 16-year-old (for GCSEs), and the proportion of A's per 18-year-old (for A-levels). Table 4 provides summary statistics of the various measures. These statistics are consistent with each GCSE candidate taking about 10 GCSE exams and each A-level candidate taking 3 A-level exams.

These results are given in Appendix Table 3 and Appendix Table 4. As before, the pupil-teacher ratio significantly negatively affects exam results in almost all of the regressions.

Table 4
Summary Statistics of Measures of Exam Performance
Secondary Schools

	A'levels	GCSEs
A's as a prop. of entries	0.209 (0.104)	0.331 (0.145)
A's per candidate	0.640 (0.340)	3.033 (1.424)
A's per 16-year-old		3.030 (1.404)
A's per 18-year-old	0.682 (0.375)	

5. Gender Effects

Gender variables were significant in the regressions in the previous section: the coefficients indicate that pupils in girls' schools have higher GCSE and A-level results than pupils in boys' or mixed schools. Furthermore, an interesting empirical fact is that many schools that are all boys until the sixth form (ages 17 and 18) admit girls at that point, but almost no girls' schools admit boys in the sixth form. In our sample of all school with GCSE and A-level candidates, there are 210 schools that have zero boys in the sixth form and 67 schools with zero girls. As demonstrated by Figure 1 below, this trend continues throughout the percentiles.

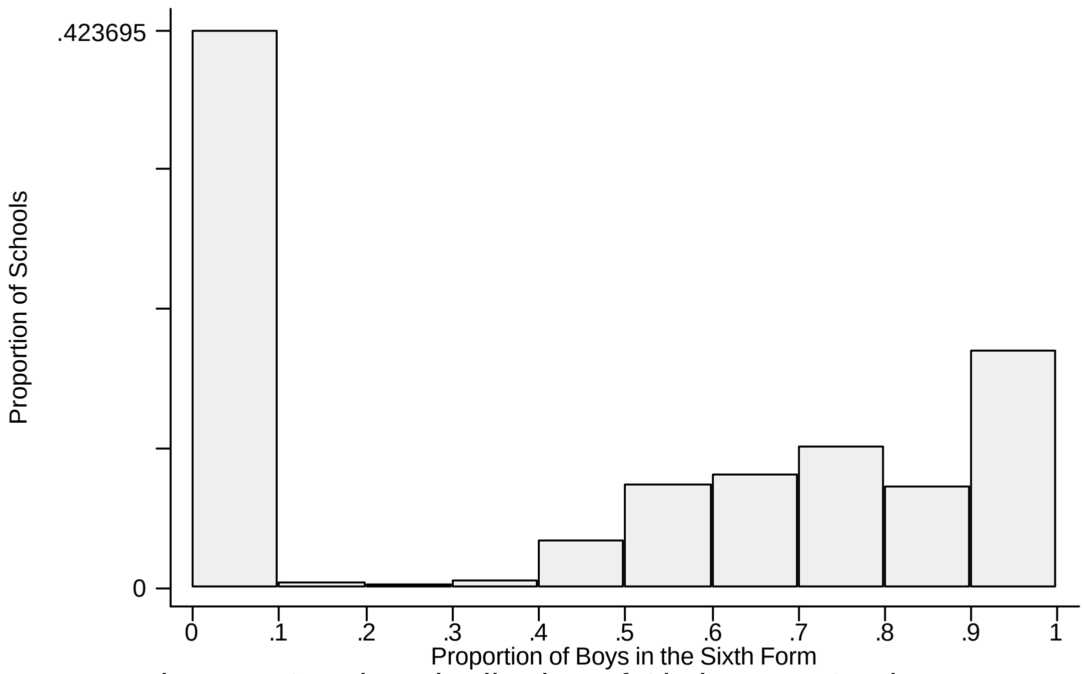

Figure 1:Gender Distribution of Sixth-Form Students

There are at least two possibilities for this asymmetry. First, the asymmetry may be demand-led: girls wish to study at historically prestigious boys' schools that also commit a large number of resources to their students. Alternatively, this effect may be an implication of Lazear's (2001) disruption model of class size effects. Lazear (2001) develops a theoretical model where class size is a choice variable. The model implies that better (behaved) students are optimally placed in larger classes, with the result that educational output appears to be higher in larger classes. If one believes that girls are better behaved than boys (or at least demand less of a teacher's time), then Lazear's model would further suggest that boys would benefit from being around girls, but girls also benefit from being around other girls due to behavioural effects. Furthermore, in Lazear's words,

> "If there is a group of n-1 A [well-behaved] students who will let one more student into the class, all of the current classmates prefer to admit an A. Furthermore, an outside A gets more from entering an all A class than does an

outside B [poorly-behaved student]."[16]

This may be an explanation of why many schools that are all boys until the sixth form admit girls at that point, but almost no girls schools admit boys in the sixth form.

If Lazear's model is correct and if girls are either better behaved or demand less of a teacher's time than boys, then one would also expect to see that class size effects are larger for boys' schools than girls' schools. We present separate regressions for boys' schools and girls' schools that allow for both between-year and between-school variation in Table 5 below.

[16] p. 790.

Table 5
Impact of School and Student Characteristics on Academic Performance
Boys and Girls Schools

	Boys			Girls		
	A-level entry	A's per A-level entry	GCSE entry	A-level entry	A's per A-level entry	GCSE entry
A's per GCSE entry	0.672			0.583		
	(0.026)			(0.034)		
ln pupils/ teacher	-0.076	-0.130	-0.108	-0.074	-0.044	-0.025
	(0.024)	(0.041)	(0.049)	(0.038)	(0.045)	(0.054)
ln number of students	0.049	0.185	0.218	0.045	0.159	0.221
	(0.009)	(0.011)	(0.014)	(0.014)	(0.016)	(0.020)
ln capital spending per pupil	0.016	0.035	0.037	0.001	0.029	0.042
	(0.005)	(0.008)	(0.010)	(0.008)	(0.011)	(0.012)
prop. teachers who are graduates	-0.020	0.245	0.376	-0.001	0.123	0.241
	(0.045)	(0.072)	(0.081)	(0.057)	(0.063)	(0.071)
turnover	-0.046	-0.124	-0.160	0.144	0.029	-0.106
	(0.057)	(0.094)	(0.120)	(0.066)	(0.092)	(0.105)
boys in 6th form	0.001	0.057		-0.112	3.733	
	(0.022)	(0.034)		(1.141)	(0.977)	
prop. male teachers	0.065	0.268	0.410	0.056	-0.094	-0.268
	(0.048)	(0.073)	(0.086)	(0.050)	(0.060)	(0.066)
proportion boarding	-0.039	-0.114	-0.138	-0.026	0.014	0.053
	(0.012)	(0.020)	(0.024)	(0.020)	(0.029)	(0.037)
proportion new foreign pupils	0.296	0.226	0.055	0.013	-0.473	-1.009
	(0.078)	(0.171)	(0.229)	(0.135)	(0.152)	(0.174)
year dummies	4	4	4	4	4	4
	3.830	7.390	4.020	1.320	7.510	4.790
no. of obs.	513	513	513	329	329	329
R-squared	0.831	0.580	0.603	0.699	0.432	0.496

Errors reported are robust (White) standard errors.
standard errors in parentheses
All regressions contain a constant.

The results are quite interesting. The coefficient on pupil-teacher ratio is not significantly different in the value-added regression for boys than in the value-added regression for girls. However, in the regressions that do not control for previous results, results are considerably more sensitive to the pupil-teacher ratio in boys' schools. These results are consistent with Lazear's predictions.

Other interesting differences between the non-value-added regressions are:

male teachers apparently improve GCSE performance in boys' schools and worsen it in girls' schools; the negative effect of the proportion-boarding that we found in the pooled regressions seems to be driven by the boys' schools only; and the proportion of new foreign pupils has a very negative and significant effect in girls' schools. A possible explanation for this last finding is that overseas pupils have a language disadvantage, and success in subjects that require linguistic ability contributes more to average results across all subjects for girls than for boys. The large coefficient on proportion of boys in the sixth form in the girls' schools A-level regression (column 5) is due to the very small average proportion of boys in the sixth form. As the average proportion of boys in the sixth form in this sample is only .00019, the coefficient suggests that average increase in the proportion of A's at A-level is .0007.

6. Conclusion

In this paper we have shown a consistent negative relationship between the pupil-teacher ratio at a school and the average examination results at that school. Our estimates indicate that the relationship persists even when we are estimating "added-value" models where we are conditioning on previous exam results.

Our results are consistent with the behaviour of parents. Pupil-teacher ratios are an important determinant of fees[17], and parents who choose schools with low pupil-teacher ratios pay for this resource. It is reassuring to find that these schools do indeed achieve better results after controlling for other school and pupil characteristics.

However, the results are noteworthy in comparison with studies for the state sector, relatively few of which have found a consistent and significant effect. The precise reason for the stronger relationship between school resources and student

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[17] The correlation across schools between the average day fees (over the years of the survey) and the average pupil-teacher ratio is –0.68.

outcomes in our sample of private schools is not easily identifiable. Possible reasons for the stronger relationship in private schools are greater resource variation, a lower average pupil-teacher ratio, or different resource utilization. A careful analysis of the factors that can cause different resource effects is an important topic for further research.

Appendix Table 1
Variable Description

A's as prop. of A-level entries	The number of A grades as a proportion of all A-level entries.
A's as prop. of GCSE entries	The number of A (and in 1994 A*) grades as a proportion of all GCSE entries.
No. of pupils	The total number of pupils at the school.
Proportion boarding	The proportion of students who are boarding students, measured at age 14.
Proportion under 11	The proportion of students under age 11 (generally the cut-off point for secondary schools).
Pupils per teacher	The total number of pupils divided by the total number of full-time teaching staff + ½ * the total number of part-time teaching staff.
Prop. of teachers who are graduates	Total full-time teaching staff who are college or university graduates, divided by all full-time teaching staff.
Turnover	The proportion of full-time teachers that leave in a year.
Day fees	Maximum fees for day pupils in 1990 GBP.*
Boarding fees	Maximum full boarding fees in 1990 GBP.
Capital Spending per pupil	Expenditure on new buildings and equipment and on improvements to existing buildings and equipment in 1990 GBP divided by the number of pupils.
Proportion boys in 6th form	The number of boys in the 6th form divided by all pupils in the 6th form.
Founding date	The date the school was founded
Proportion new foreign pupils	The number of new foreign pupils (permanent homes outside UK) as a proportion of total pupils

*Fees for the lower age-groups are sometimes less than fees for older students and are recorded in the survey as minimum day fees. Fees are reported per term, with three terms in a year.

Appendix Table 2
Impact of Resources on Academic Performance
All Schools
A's as a proportion of entries

	Between and Within School Effects			Between School Effects			Within School Effects		
	A's as a proportion of			A's as a proportion of			A's as a proportion of		
	A-level entries	A-level entries	GCSE entries	A-level entries	A-level entries	GCSE entries	A-level entries	A-level entries	GCSE entries
A's as a prop. Of GCSE entries	0.635 (0.017)			0.702 (0.034)			0.368 (0.034)		
ln pupils/ teacher	-0.076 (0.011)	-0.096 (0.016)	-0.069 (0.021)	-0.067 (0.017)	-0.099 (0.031)	-0.077 (0.040)	-0.078 (0.026)	-0.052 (0.027)	0.017 (0.026)
ln number of students	0.031 (0.004)	0.131 (0.005)	0.167 (0.006)	0.023 (0.007)	0.132 (0.010)	0.165 (0.013)	0.059 (0.032)	0.062 (0.033)	0.008 (0.024)
ln capital spending per pupil	0.003 (0.002)	0.013 (0.004)	0.021 (0.004)	0.002 (0.003)	0.012 (0.006)	0.019 (0.008)			
prop. teachers who are graduates	-0.020 (0.027)	0.180 (0.031)	0.329 (0.031)	-0.044 (0.042)	0.201 (0.057)	0.362 (0.066)	-0.022 (0.048)	-0.007 (0.049)	0.007 (0.045)
turnover	0.068 (0.030)	-0.009 (0.038)	-0.156 (0.041)	0.096 (0.053)	-0.097 (0.079)	-0.312 (0.101)	0.096 (0.040)	0.098 (0.041)	-0.035 (0.032)
other covariates*	9	9	8	9	9	8	4	4	3
year dummies	4	4	4				4	4	4
school dummies							497	497	497
no. of obs.	2389	2389	2389	498	498	498	2389	2389	2389
R-squared	0.683	0.383	0.531	0.830	0.463	0.584	0.822	0.802	0.907

Errors reported are robust (White) standard errors, all regressions include a constant
*Number. of other covariates excluding year and school dummmies

Appendix Table 3
Impact of Resources on Academic Performance
Secondary Schools
A's as a proportion of candidates

	Between and Within School Effects			Between School Effects			Within School Effects		
	A's as a proportion of			A's as a proportion of			A's as a proportion of		
	A-level candidates	A-level candidates	GCSE candidates	A-level candidates	A-level candidates	GCSE candidates	A-level candidates	A-level candidates	GCSE candidates
A's as a proportion of GCSE candidates	0.214 (0.006)			0.234 (0.011)			0.121 (0.012)		
ln pupils/ teacher	-0.200 (0.047)	-0.383 (0.071)	-1.117 (0.251)	-0.138 (0.073)	-0.443 (0.150)	-1.387 (0.560)	-0.236 (0.092)	-0.152 (0.101)	-0.059 (0.273)
ln number of students	0.118 (0.017)	0.502 (0.021)	1.971 (0.083)	0.080 (0.027)	0.504 (0.040)	1.973 (0.172)	0.191 (0.110)	0.253 (0.116)	-0.123 (0.271)
ln capital spending per pupil	0.023 (0.010)	0.089 (0.015)	0.342 (0.054)	0.019 (0.014)	0.086 (0.029)	0.309 (0.108)			
prop. teachers who are graduates	-0.039 (0.090)	0.534 (0.120)	2.881 (0.430)	-0.134 (0.115)	0.544 (0.230)	2.832 (0.899)	0.039 (0.185)	0.084 (0.198)	0.981 (0.489)
turnover	0.171 (0.108)	0.042 (0.159)	-0.438 (0.604)	0.099 (0.193)	-0.208 (0.400)	-1.222 (1.491)	0.270 (0.145)	0.257 (0.151)	0.532 (0.426)
other covariates*	8	8	7	8	8	7	3	3	2
year dummies	4	4	4				4	4	4
school dummies							266	266	266
no. of obs.	1233	1233	1233	267	267	267	1233	1233	1233
R-squared	0.786	0.503	0.564	0.888	0.548	0.600	0.880	0.874	0.936

Errors reported are robust (White) standard errors, all regressions include a constant
*Number of other covariates excluding year and school dummmies

Impact of Resources on Academic Performance
Secondary Schools
(A's as a Proportion of 16 or 18-year-olds)

	Between and Within School Effects			Between School Effects			Within School Effects		
	A's as a proportion of			A's as a proportion of			A's as a proportion of		
	18-year-olds	18-year-olds	16-year-olds	18-year-olds	18-year-olds	16-year-olds	18-year-olds	18-year-olds	16-year-olds
A's at GCSE level as a prop. Of 16-year-olds	0.229 (0.008)			0.260 (0.014)			0.115 (0.015)		
ln pupils/ teacher	-0.273 (0.059)	-0.458 (0.082)	-1.085 (0.256)	-0.250 (0.097)	-0.576 (0.176)	-1.418 (0.563)	-0.203 (0.121)	-0.130 (0.128)	0.164 (0.298)
ln number of students	0.128 (0.021)	0.526 (0.027)	1.908 (0.085)	0.077 (0.031)	0.533 (0.048)	1.905 (0.171)	0.277 (0.193)	0.346 (0.194)	-0.145 (0.309)
ln spending per pupil	0.017 (0.012)	0.088 (0.017)	0.342 (0.056)	0.011 (0.017)	0.087 (0.033)	0.311 (0.109)			
prop. teachers who are graduates	0.005 (0.109)	0.559 (0.143)	2.576 (0.435)	-0.136 (0.139)	0.544 (0.270)	2.555 (0.891)	0.239 (0.403)	0.235 (0.406)	0.609 (0.611)
prop. Turnover	0.443 (0.163)	0.247 (0.207)	-0.572 (0.609)	0.302 (0.285)	-0.095 (0.465)	-1.495 (1.498)	0.627 (0.240)	0.577 (0.246)	0.387 (0.468)
other covariates*	8	8	7	8	8	7	3	3	2
year dummies	4	4	4				4	4	4
school dummies							266	266	266
no. of obs.	1233	1233	1233	267	267	267	1233	1233	1233
R-squared	0.694	0.436	0.547	0.848	0.509	0.591	0.830	0.817	0.919

Errors reported are robust (White) standard errors, all regressions include a constant
*No. of other covariates excluding year and school dummmies

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