THE IMPACT OF SCHOOL INPUTS ON STUDENT PERFORMANCE: AN EMPIRICAL STUDY OF PRIVATE SCHOOLS IN THE UNITED KINGDOM

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The data and programs used to generate the results presented in this paper are available from the authors, for replication purposes, upon request.

Abstract

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, using a new school-level panel dataset constructed from information provided by the Independent Schools Information Service. We show a consistent negative relationship between the pupil-teacher ratio at a school and the examination results achieved by pupils aged 18, after controlling for their performance in examinations two years earlier. The results are noteworthy in comparison with studies for the state sector, relatively few of which have found a consistent and significant effect of the pupil-teacher ratio.

In this article, we report the results of an empirical study of the impact of school inputs on pupils' examination performance at secondary level in private (also known as "independent") schools in the United Kingdom. We use a new dataset constructed from information provided by the Independent Schools Council information service (ISCis). This is a school-level panel dataset for the years 1988-1994 and includes resource information, examination results at ages 18 and 16, and fees, from UK private schools.

This is an exploratory study: we investigate whether school resources matter for student achievement. This question has been debated for at least 30 years, primarily with data from state ("public" in North America) schools. The evidence in the US and the UK has been mixed, with several recent UK studies (described below) finding no effects from the pupil-teacher ratio.

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. Furthermore, on average private schools have a lower pupil-teacher ratio than state schools, and may also organise teaching differently; for both of these reasons, resource effects may be different. 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.

Private schools also differ from state schools in that the majority are single-sex over most of the age range, while the majority of state schools are mixed. We are therefore able to look for systematic differences in the determinants of examination results in boys' and girls' schools, and to examine in particular whether teaching resources affect them differently.

Resource Effects on Performance: Related Literature

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 study that is most similar to ours is by Bradley and Taylor (1998). Using UK school-level data from the Secondary School Performance Tables for the years 1992 and 1996, they find that the level of the pupil-teacher ratio has no effect on the level of exam performance at age 16; there is a significant but very small effect of the change in the pupil-teacher ratio on the change in exam performance.

Several papers that have looked directly at the impact of changes in the pupil-teacher ratio on academic achievement at secondary level[1] have used data from the National Childhood Development Study (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, Dustmann, Rajah, and Von Soest (2002) find that class size impacts the decision of whether or not to stay on at school, and through this mechanism affects wages.

In an influential series of papers, Eric Hanushek (1986, 1989, 1996a, 1996b, 1997, 1998) reviews the many studies of the impact of school resources (particularly class size or pupil-teacher ratio) on student achievement in US schools. He claims, "There is no strong or consistent relationship between school inputs and student performance."[2] However Krueger (2000) argues that Hanushek's approach gives undue weight to a small number of studies that report many estimates, and that when studies are weighted equally resources are systematically related to achievement.

Many past studies are vulnerable to the criticism that class size is endogenous. This problem is explicitly addressed in more recent work. In the Tennessee Student/Teacher

Achievement Ratio (STAR) experiment students and teachers were randomly assigned to classes of different sizes, and test scores are found to be higher for those in smaller classes (see Mosteller (1995), Krueger (1999), and Krueger and Whitmore (2001)). Several recent papers, with data for various countries, use instrumental variables: Akerhielm (1995), Angrist and Lavy (1999), Sander (1999), and Boozer and Rouse (2001) all find significant, although in some cases modest, effects of class size on achievement, but Hoxby (2000) finds no effect.[3]

All these studies have taken the bulk of their data from the public sector. Private schools in the UK differ from state schools in having a considerably higher average level of resources per pupil. In particular they have a lower pupil-teacher ratio, and effects may be different in this range: the well-known meta-analysis of Glass and Smith (1979) suggested that the benefits of class-size reduction are greater for classes of fewer than 15 students. It is also possible that teaching is organised differently in private schools, as suggested by Dearden, Ferri, and Meghir (2002, p. 9) as a possible explanation for the better educational outcomes they observed in NCDS for individuals who attended private schools.

A 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 age 18, is determined by the resource inputs of the school (including the pupil-teacher ratio). Since performance depends also on variables for which we cannot fully control, 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 studies, but the nature of the problem depends on the sample of schools. Thus for private schools we do not need to be concerned about the effects of public education policy (as were Dearden, Ferri and Meghir, 2001). The problem emphasised by Hoxby (2000) for US public schools, that parents who choose to live in school districts with lower pupil-teacher ratios also contribute directly to their children's education, is similarly less relevant because we may assume that all parents who value education sufficiently to pay for it also provide direct support. To establish the particular endogeneity issues that arise from parental choice of private education we develop a simple model of resource determination in UK private 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.

Suppose that the examination results r obtained by a student depend positively upon the resource inputs of the school, q, the ability a of the student, and also on the peer group – specifically the average ability A of pupils in the school[4]: $r=r(q, a, A)$. "Ability" may be broadly interpreted, to capture any individual characteristics of the child that lead to educational success: motivation and compliance may be as important as natural talent. Families are characterised by income level y and child-ability a; family-utility depends on consumption and the educational outcome. As we show in more detail in the Appendix, the family has a desired level of school resources, $q^*(y, a)$. Since each family prefers a school that excludes children of lower ability than its own child, children are sorted across schools by ability. This can be achieved by each school setting an entrance standard, which is exactly what we see in the UK private education market, where there is a hierarchy of schools with more or less stringent entry requirements.

For simplicity, we assume a discrete distribution of family-types (y, a); then, in equilibrium, there is a school-type for each family-type (so $A=a$). Hence school examination results are given by:

$r(q^*(y,a), a, a)$

This expression illustrates clearly the problem we face in trying to identify the effect of resources, q, on the examination results of the school: the observed resource level depends on the ability of the children in the school, which also affects results directly. If we cannot control for ability the estimate will be biased. Note also, however, the dependence on family income ($\partial q^*/\partial y > 0$) which will induce variation in resources across schools, and hence, provided that family income is uncorrelated with child-ability, help us to identify the effect we are interested in. Correlation between income and ability is relatively unlikely in the UK Independent Schools sector, because all families buying private education are in the upper strata of the income distribution.

Sources of Bias

In our model the effect of ability on school resources, $\partial q^*/\partial a$, and hence the direction of the potential bias, can be decomposed into four effects (see Appendix):

	Effect of a on q^*
A child with high ability will get good results anyway	Negative
A child with high ability benefits from high ability peers	Negative
Returns to resources increase/decrease with individual ability	Positive/Negative
Returns to resources increase/decrease with average ability	Positive/Negative

The overall direction of the bias is ambiguous; it depends on whether educational resources have more effect on the results of lower or higher ability children. There is some evidence (Angrist and Lavy, 1999; Krueger and Whitmore, 1999) that class-sizes matter more for disadvantaged students, in which case the third effect above would be negative. Lazear (2001) presents a model in which the fourth effect is negative: the return to teaching resources is lower when the average ability (behaviour) of children in the class is higher. Some studies find that that teachers assign lower ability children to smaller classes

(Akerhielm,1995; Boozer and Rouse, 2001), but this does not necessarily imply higher returns.[5] Overall the evidence on this issue is not extensive, and since it is also plausible that returns to resources increase over some parts of the ability range, we cannot rule out a positive bias.

In our regressions we are able to 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, we control for the results of the same 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 may be interpreted as value-added results, but previous exam performance is an imperfect proxy for pupil ability since it 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.

Another concern is omitted resource variables such as quality of teaching and the skills of teachers, which have been shown to be important in past work (Hanushek, 1992). Our only control for teacher quality is the percentage of teachers who are graduates. A positive bias in the coefficient on the pupil-teacher ratio would arise if schools with a low ratio were inclined to hire better teachers (although it may be the smaller classes that attract these teachers).

Our measure of resources is the school-wide pupil-teacher ratio. Since we model performance at age 18 and control for performance at age 16, we would prefer to have class-sizes for pupils in the last two years of their education (known as the "sixth form"). The problem is not that class-sizes within schools differ by ability (since selection policies lead to a narrow ability range) but that they decrease through the age range after a maximum in the middle of the primary years. To reduce this problem, we focus on the sub-sample of schools with secondary age pupils only.

We have a panel dataset, allowing exploitation of the within-school variation of the pupil-teacher ratio, but this variation may not be random. Investigation of the changes in the pupil-teacher ratio in our dataset showed that about half were driven by greater proportional changes in teacher numbers, and half by changes in pupil numbers. One reason for pupil numbers to change is that although many pupils remain in the same school when compulsory education ends at age 16, some 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 short-term fluctuations. Such variation is likely to lead to changes in class sizes in the sixth-form, rather than for younger pupils, since a school typically has only one or two classes of sixth-formers studying each subject.

Given that pupils may leave education or change schools at age 16, the ability of the group of pupils taking exams at age 18 may not be well-represented by the school's results two years earlier. Either the decisions of pupils, or school policy, may lead to selection of pupils after age 16. Similarly, changes in teacher numbers may be an endogeneous response to the effectiveness of the school. Such effects could introduce a bias if they occurred systematically across schools and were correlated with the pupil-teacher ratio and exam results. We can capture them partially by controlling for teacher and pupil turnover, but we cannot control directly for changes in pupil ability or other resource variables.

The Empirical Model

The considerations above lead us to the following model specification. Let y_{st} represent a measure of examination results at age 18 in school s in year t, and z_{st} be a vector of variables representing 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

$$y_{st} = \gamma' R_{st} + \beta' P_{st} + \varphi' z_{st\text{-}2} + \sigma_s + \delta_t + \varepsilon_{st} \qquad (1)$$

where δ_t and σ_s represent year-specific and school-specific fixed-effects and ε_{st} is an error term. We focus mainly on this school-fixed-effects model (within-school estimates), but also present estimates where σ_s is restricted to be zero (within- and between-school estimates).

Data and Background

Just under 7% of school pupils in England[6] attend independent schools, for which their parents pay fees. This figure has remained more or less constant since 1988 (the beginning of our data period). Independent schools are much more disparate than state schools: 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.

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 performance in national examinations (described below), which are critical for a student's future career opportunities and university entry. 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 (which is closely related to the pupil-teacher ratio, as described below) is of the order of 40% of median disposable income for UK households, and 20% for households at the 90th percentile.

The data in this study were collected by the Independent Schools Council information service (ISCis), 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 (when we measure performance) and we focus mainly on those that we can classify as "secondary" schools (fewer than 5% of pupils under age 11). We model examination performance for the five years 1990-1994, using the 1988 and 1999 data for lagged variables.

Almost all students in the UK (95%) take national standardised examinations[7], known as GCSEs (General Certificate of Secondary Education), at the end of the final year of compulsory education at age 16. They receive a separate grade for each subject entered. Good students, intending to stay on into post-compulsory education, typically enter nine or ten subjects, and hope to achieve grades A to C. For the schools in our study we know the number of candidates, the total number of entries (that is, candidate-subjects), and the number of entries awarded each grade. Our measures of the school's performance are the proportion of entries awarded an A grade, the proportion awarded grade A or B, and the proportion awarded A-C.

Around 30% of the age group (and 80% of those in private schools) take further 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 order to do so. Most students take A-levels in three subjects of their own choice, receiving a separate grade for each. Passing grades are A to E, and we measure performance by the proportions of entries[8] graded A, A-B, and A-C.

Table 1 presents summary statistics for examination performance for our full sample of 498 schools, and for the sub-sample of 267 secondary schools. A list of variable definitions is given in Appendix Table 1. The statistics reported are averages over the period 1990-1994.

[*Table 1 here*]

For each variable we present the mean for the group of schools within each quartile of the distribution of the proportion of A-grades at A-level. Note the large disparity in A-level results by school: the average proportion of A's at A-level is .096 in the lowest quartile, and .351 in the highest. A similar disparity is evident in the other measures of performance. The number of candidates is close to the number of pupils in the relevant age-group, but not identical: a few pupils do not take the exams, or take them at different ages.

On average each GCSE candidate enters for about 9 subjects and each A-level candidate for about 3 subjects. The better performing schools are considerably larger, with a slightly higher number of entries per candidate (so there appears to be no trade-off between quantity and quality of results). Finally, note that in the best performing schools there is a smaller decline in the number of students between age 16 and age 18, as more students stay on at school to study for A-levels.

School and Pupil Characteristics

For each school the annual census records the total number of pupils and their distribution by age, numbers of full-time and part-time teaching staff, the proportion of these who are university or college graduates, and the number of teachers leaving and entering each year. From pupil and staff numbers we calculate school-wide pupil-teacher ratios[9]. We know the number of new pupils entering post-GCSE, and since we have the number of pupils in each cohort we can infer the number who leave post-GCSE. Summary statistics for these and other variables recorded in the survey are reported[10] in Table 2. See Appendix Table 1 for more information on variable definitions.

[*Table 2 here*]

As before the summary statistics are averages for 1990-1994, by quartile of the A-level results distribution. Fees and capital spending have been adjusted for inflation. Some of these 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. There are strong negative correlations with teacher turnover, and founding date (schools founded earlier achieve better results). Looking at our measures of student turnover post-GCSE, fewer students drop out in the better performing schools, but those in the middle of the results distribution have a larger intake of new students.

The average level of the pupil-teacher ratio is 10 for secondary schools and 11 for the full sample. Consistent with our theoretical model it varies widely, from 7.9 at the 10th percentile to 14.2 at the 90th percentile, but it is notably lower than in state schools even at the top of the range. Table 3 presents figures for comparison, showing also that pupil-teacher ratios have fallen in independent schools, while rising in the state sector.

[*Table 3 here*]

The huge difference in teaching resources is reflected in costs. Within our sample of independent schools the correlation between day fees and the pupil-teacher ratio is –0.68; in 1993/1994 the average annual fee for older day pupils was £5004, while average total spending per pupil in state secondary schools in 1994/1995 was £2320.

Interestingly, we can see from Table 2 that in our sample the pupil-teacher ratio is positively correlated with exam results. This is consistent with higher ability students being placed in schools with a high pupil-teacher ratio.

We can examine whether selection of pupils after GCSE is a potential concern, by looking at the correlation between turnover (represented by the number of students who enter and leave as a proportion of all 16 year-olds) and the pupil-teacher ratio. Table 4 does not indicate a strong association, but fewer students enter the schools where the pupil-teacher ratio is highest and more leave the schools where it is lowest, suggesting that it is important to control for the turnover variables in our regressions.

[*Table 4 here*]

Estimation and Results

In estimating model (1) the variables we use for R_{st} (measured resources for a particular school) are pupils per teacher, number of students, capital spending per pupil, the proportion of teachers who are graduates and staff turnover. Pupil characteristics, P_{st}, are the proportions of boarding pupils, new foreign pupils, and boys in the sixth-form, and the proportions entering and leaving post-GCSE. We expect the 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 an important pupil characteristic, but in addition girls' schools may differ systematically from boys' schools, which are the longer established schools in the sample, and have different traditions. 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. Schools defined as "boys" may nevertheless have significant numbers of girls in the sixth form. In the model without school fixed-effects we include dummy variables for boys' and girls' schools, and interactions with the gender of teachers. Gender effects are discussed in detail in a separate section below.

We take logs of variables that are not proportions or dummy variables (pupil-teacher ratio, school size and capital spending), except teacher turnover for which some observations are zero. Since students study for two years for A-levels, we average our independent variables over the current and previous year. The only variable that we treat differently is capital spending. 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, so we average it over the seven years of the study for each school, and exclude it when including school fixed-effects.

Our results are reported in Table 5, for each of the three measures of A-level performance. Looking first at the fixed-effect regressions, there is a negative relationship between the pupil-teacher ratio and all three measures of A-level examination performance, conditional on GCSE results. For the proportion of A's at A-level the coefficient on the log of the pupil-teacher ratio is 0.079. Since the mean proportion of A's is 0.209, this corresponds to an elasticity of 0.38 at the mean. Equivalently, a reduction of the pupil-teacher ratio from 10 (the mean) to 9 would lead to a 4% improvement in this measure of A-level performance. When A-B's or A-C's as a proportion of A-level entries are used as the dependent variable, the coefficient on the pupil-teacher ratio is around 0.1, corresponding to elasticities at the mean of 0.24 and 0.16 respectively.

[*Table 5 here*]

School size is not significant at the 5% level in these fixed-effect value-added regressions. The proportion of teachers who are graduates does not affect the proportion of A-grades, but has a positive and significant effect on A-B grades and A-C grades. Teacher turnover is significant at the 10% level for A-grades only, and seems to have a positive effect. Perhaps unsurprisingly, the proportions of boys, boarders, and new foreign pupils, none of which change markedly from year to year, do not significantly affect value-added within-school performance. Finally, the proportion of new post-GCSE students has a negative effect on the proportion of A-C grades. More people leaving post-GCSE affects results positively, indicating that weaker students are leaving.

Alternative Specifications

Equations with both between- and within-school effects ($\sigma_s = 0$), also shown in Table 5, allow for greater variation in the pupil-teacher ratio, but may suffer from school selection bias. In this specification our controls for ability, GCSE results, become very important in predicting A-level performance. Nonetheless, coefficients on the other variables, including the pupil-teacher ratio, are similar to those in the fixed-effects model. The exceptions are the proportions of boarding pupils (schools with higher numbers of boarders achieve significantly fewer A grades), and the proportion of foreign pupils (which now has a positive effect, significant only at the 10% level). School size becomes highly significant (larger schools do better), and capital spending, which was not included in the fixed-effects model, has a significant effect on the proportion of A grades.

A number of robustness checks were performed. We estimated the equations with this year's and last year's resource variables entered separately, rather than averaging them over two years. The resource coefficients for the two years were very similar, and far from statistically significantly different from each other. Also, since the number of GCSE and A-level subjects taken can vary by individual, we estimated the models with the number of A's per candidate as the dependent variable, and the number of GCSE grades per candidate as a control, but found that this made little difference to the results.

Gender Effects

Nationally, the academic performance of girls relative to boys has been improving; during our data period girls obtained better GCSE results than boys, but boys did better at A-level; more recently, girls have overtaken boys at A-level too. In the fixed-effects regressions in Table 5 a within-school increase in the proportion of boys has a negative but insignificant effect on A-level results. Allowing for between-school variation, the effect is somewhat stronger, and significant for the broadest measure of results.

Our dataset allows us to compare the performance of boys' and girls' schools. An interesting empirical fact is that many schools that are boys-only until age 16 admit girls at that point, but very few girls' schools admit boys. The resulting gender distribution of 6th form students is shown in Figure 1. This asymmetry may be demand-led: girls wish to study at historically prestigious boys' schools that also commit a high level of resources to their students. Alternatively, it may be an implication of Lazear's (2001) disruption model of class size effects, which implies that better (behaved) students are optimally placed in larger classes. If one believes that girls are better-behaved than boys, or at least demand less of a teacher's time, the 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. This may help to explain why boys' schools are more willing to admit girls in the sixth form than vice-versa. In addition, if girls do demand less of a teacher's time than boys, then Lazear's model would suggest that class size effects should be larger for boys' schools than girls' schools.

[*Figure 1 here*]

We present separate regressions for boys' schools and girls' schools in Table 6, for the broadest measure of A-level results. Coefficients are generally similar to those in Table 4, but standard errors are much higher, probably due to the smaller sample. In the fixed-effects regressions the coefficient on pupil-teacher ratio is not significantly different from zero at the 5% level, either for boys' or girls' schools. When between-school variation is allowed, it does appear that the pupil-teacher ratio may matter more for boys' schools, although the coefficients are not significantly different from one another.

[*Table 6 here*]

Other differences between the two samples are suggested by the non-fixed-effects regressions; the corresponding coefficients in the fixed-effects models have the same sign but are not significantly different from zero. Foreign pupils are associated with better exam results in boys' schools but worse results in girls' schools; also in girls' schools boarders are associated with better results. The proportion of male teachers seems to have opposite effects in boys' and girls' school, but the coefficients are not significant. Unexpectedly, the proportion of boys in the sixth form has a positive effect for girls' schools, which might suggest that both boys and girls benefit from being in mixed sixth form classes. But since the coefficient is significant only in the regression without fixed-effects, and only a small number of girls' schools admit any boys, an alternative interpretation is that a few more successful girls' schools can attract boys.

Regressions using the other performance measures exhibited rather less difference between the two samples, even without fixed effects; arguably one would expect gender effects to be less pronounced for the best-performing students. Overall the results provide only weak support for the interpretation of Lazear's model in terms of gender.

Conclusion

In this paper we demonstrate a consistent negative relationship in UK independent schools between the pupil-teacher ratio at a school and the average examination results for 18-year-old pupils at that school. Like other studies we face the problems of unobserved pupil ability and school resources; we are able to address these problems by controlling for examination performance at age 16 and, since we have a panel dataset, using school fixed effects. We obtain very similar estimates of the coefficient on the pupil-teacher ratio in specifications with and without school fixed effects: these indicate that a 10 percent reduction in the school-wide pupil-teacher ratio leads to a 4 percent increase in the percentage of A-grades in A-level examinations. Having investigated the differences between the determinants of results at girls' and boys' schools, we find only weak support for the hypothesis that the pupil-teacher ratio matters more in boys' schools.

Many parents in the UK who choose private education spend a high proportion of family income on school fees, and pupil-teacher ratios are an important determinant of fees: parents who choose schools with a low pupil-teacher ratio pay for this resource. Our findings are consistent with their apparent belief that a lower pupil-teacher ratio is desirable: these schools do indeed achieve better results after controlling for other school and pupil characteristics.

Our results are noteworthy in comparison with studies for the state sector, relatively few of which have found a consistent and significant effects of school resources. Studies for UK state secondary schools, in particular, have found little or no effect of the pupil-teacher ratio. Our finding of a stronger effect for private schools can probably be attributed, at least in part, to differences we find in the data: the pupil-teacher ratio varies widely, so its effect is easier to identify; secondly the pupil-teacher ratio is lower than in state schools and the effect of reducing class sizes may be greater when classes are already small. It is also possible that teaching is organised differently in private schools but we have no direct evidence to support this hypothesis.

Appendix: A Model of Resource Determination in UK Independent Schools

Consider a discrete distribution of families, each with a single child, differing in family income, y, and the ability of the child, a. A family of type (y, a) cares about consumption, and the test results obtained by the child. Its utility is $u(y\text{-}f, r)$ where f is school fees, r is results, and u is increasing and concave in both arguments. A natural assumption is $u_{12}\geq 0$: the marginal utility of good results is non-decreasing with family consumption.

The child's results, r, depend positively on the total educational input per child, or *quality*, q, provided by the school, the child's ability, a, and the average ability of pupils in the school, A: $r=r(q, a, A)$. Educational quality q depends on the vector $\underline{e}$ of individual inputs (teachers, books and other resources) per pupil: $q=Q(\underline{e})$.

The non-profit-making school chooses inputs $\underline{e}$ to minimise the cost of producing educational quality q, at factor prices w: it minimises $\underline{w}.\underline{e}$ subject to $Q(\underline{e})= q$, and sets fees equal to cost per pupil: $f(q) = \underline{w}.\ \underline{e}^*(q)$. The school may also select pupils by ability, which will determine average ability A.

Schools enter the market to supply the type of education (quality and selection policy) desired by each family type. A family of type (y, a) wants quality q and average ability in the school A to maximise: $u\big(y - f(q), r(q,a,A)\big)$. Clearly, it wants A to be as high as possible, subject to the constraint that its own child meets the selection criteria. It therefore prefers a school that excludes children of ability less than a. Although it would prefer the school also to admit children of higher ability, in equilibrium they choose a different school. Hence the child attends a school where the average level of ability is equal to a. The family's desired educational quality is: $q^*(y,a) = \arg\max u\left(y - f(q), r(q,a,a)\right)$. In equilibrium there is a school-type corresponding to each family-type (y, a), with a selection threshold a, and the quality q^* desired by this family-type. The results for each child in the school are given by $r(q^*(y,a), a, a)$. It follows immediately from the first-order condition for q^* that:

(i) School resources are increasing in family income: $\frac{\partial q^*}{\partial y} \overset{\text{sgn}}{=} -u_{11}f_1 + u_{12}r_1 > 0$

(ii) Resources depend on ability according to: $\frac{\partial q^*}{\partial a} \overset{\text{sgn}}{=} \left[-u_{12}f_1 + u_{22}r_1\right](r_2 + r_3) + u_2 r_{12} + u_2 r_{13}$

The first term $\left[-u_{12}f_1 + u_{22}r_1\right](r_2 + r_3)$ is negative. Its interpretation is that parents of high ability children choose lower resources, partly because the child will get good results anyway (r_2) and partly because it will be helped by the high ability of other children in the school (r_3). The signs of the other terms are ambiguous; they depend on how the child's own ability, and the ability of other children, affect the individual return to educational inputs (r_{12} and r_{13} respectively). See the main text for discussion.

[*Appendix Table 1 here*]

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[1] Little evidence is available at Primary level. However Gibbons (2002), using school-level data from the Department for Education and Skills, finds that an additional qualified teacher for each 100 pupils leads to a 2.6 percentage point improvement in success rates.

[2] Hanushek, 1997, p. 148.

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

[4] Peer group effects have been the subject of much debate (Robertson and Symons, 1996) and it may not be plausible to assume that, for example, a child at the lower end of the ability range benefits from being is a class with those at the opposite extreme. In fact, all we really need for the model is for the peer group effect to hold locally – the child does better when the average ability in the school is just above, rather than just below, his own ability.

[5] At the opposite end of the ability range there is a particular group of schools in our dataset, belonging to the Girls' Day School Trust (GDST), that accept only pupils of the highest ability. GDST schools have high pupil-teacher ratios (in the top 10% of our sample), and low fees.

[6] 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.

[7] The description of the examination system refers to our data-period; some changes occurred before and after that time.

[8] It might seem that a better measure of performance would be grades per candidate, particularly if schools try to raise average performance by reducing the number of entries per candidate. But this is not the case: the primary objective of schools and pupils is "three good A-levels" – the requirement for entry to higher education. The most common reason for departure from the three-subject norm is that some schools also enter pupils for a "General Studies" A-level. We are concerned that measuring performance by grades per candidate would give undue weight to General Studies, which normally requires little extra teaching and is not as highly regarded as other subjects. However, we also try this measure as a robustness check.

[9] Zeros were entered in the survey where the school did not answer a question, causing some confusion. Observations containing a zero for total number of pupils or teachers were dropped. Those containing zero for staff turnover (59 out of a total of 1233 observations) were retained. The variable used in the regressions was average turnover over two years, for which zeros occurred only four times.

[10] Other available variables, not reported, are: the financial status of the school (charitable, limited company, or proprietary status), pupils with parents in H.M. Forces, and the proportion receiving financial contributions to fees from central or local government or the school itself.

Table 1
Summary Statistics: National Examinations

Variable*	Secondary Schools					All Schools
	Quartiles of the A-level Results Distribution (A-grades as a proportion of entries)					
	1st quart.	2nd quart.	3rd quart.	4th quart.	All	Full Sample
A-grades as a proportion 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-grades as a proportion 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)
A-Bs as a proportion of A-level entries	0.246 (0.067)	0.363 (0.038)	0.454 (0.035)	0.599 (0.088)	0.415 (0.142)	0.415 (0.139)
A-Bs as a proportion of GCSE entries	0.428 (0.112)	0.573 (0.085)	0.666 (0.069)	0.811 (0.085)	0.619 (0.165)	0.636 (0.164)
A-Cs as a proportion of A-level entries	0.434 (0.095)	0.567 (0.053)	0.657 (0.050)	0.779 (0.068)	0.609 (0.143)	0.605 (0.138)
A-Cs as a proportion of GCSE entries	0.731 (0.106)	0.840 (0.061)	0.899 (0.043)	0.956 (0.033)	0.852 (0.107)	0.862 (0.107)
Number of A-level entries	105.657 (59.147)	178.811 (79.338)	283.698 (121.033)	338.656 (148.434)	226.286 (140.159)	189.559 (133.704)
Number of GCSE entries	501.614 (181.504)	636.437 (218.814)	875.313 (276.830)	1034.124 (378.925)	760.852 (341.775)	683.148 (338.317)
Number of A-level candidates	36.900 (20.192)	59.569 (25.677)	91.411 (37.707)	107.922 (45.880)	73.823 (43.507)	62.221 (41.950)
Number of GCSE candidates	58.060 (18.862)	71.759 (23.413)	93.109 (28.514)	109.613 (39.634)	83.036 (34.639)	75.205 (34.463)
Number of 18 year olds	35.814 (19.167)	57.532 (25.096)	87.077 (36.095)	101.905 (45.494)	70.465 (41.663)	59.528 (40.230)
Number of 16 year olds	57.425 (19.216)	71.871 (24.151)	94.151 (29.080)	110.545 (39.917)	83.397 (35.368)	75.400 (35.306)

*Please see Appendix Table 1 for variable construction

Table 2
Summary Statistics: School and Pupil Characteristics

Variable*	Secondary Schools					All Schools
	Quartiles of the A-level Results Distribution (A-grades as a proportion of entries)					
	1st quart.	2nd quart.	3rd quart.	4th quart.	All	Full Sample
number of students	307.624	409.415	557.732	666.619	484.669	536.492
	(107.439)	(149.666)	(178.167)	(232.465)	(219.963)	(250.942)
proportion of boarding pupils	0.492	0.475	0.489	0.381	0.460	0.312
	(0.336)	(0.335)	(0.335)	(0.407)	(0.355)	(0.343)
proportion of pupils aged under 11	0.006	0.005	0.005	0.005	0.005	0.144
	(0.007)	(0.005)	(0.009)	(0.007)	(0.007)	(0.163)
pupils per teacher	9.329	9.521	9.726	10.333	9.725	10.880
	(1.815)	(1.884)	(1.687)	(2.024)	(1.883)	(2.337)
proportion of teachers who are graduates	0.872	0.903	0.928	0.936	0.910	0.852
	(0.092)	(0.073)	(0.050)	(0.058)	(0.074)	(0.119)
teacher turnover	0.115	0.104	0.085	0.085	0.097	0.099
	(0.050)	(0.045)	(0.038)	(0.032)	(0.044)	(0.047)
day fees	1474.824	1576.701	1613.616	1527.035	1548.287	1349.264
	(374.635)	(392.978)	(437.107)	(473.007)	(420.552)	(414.072)
boarding fees	2507.345	2532.335	2494.643	2789.229	2566.276	2455.621
	(302.427)	(499.425)	(507.315)	(464.719)	(462.900)	(468.220)
capital spending per pupil	614.714	745.807	854.860	1069.269	820.233	613.243
	(466.920)	(444.934)	(822.392)	(833.206)	(684.391)	(586.231)
proportion of boys in 6th form	0.560	0.519	0.614	0.586	0.569	0.443
	(0.395)	(0.329)	(0.343)	(0.428)	(0.375)	(0.407)
proportion of new post-GCSE students	0.105	0.156	0.166	0.112	0.135	0.111
	(0.097)	(0.122)	(0.129)	(0.103)	(0.116)	(0.101)
proportion of post-GCSE leavers	0.523	0.379	0.284	0.213	0.350	0.396
	(0.177)	(0.156)	(0.125)	(0.122)	(0.187)	(0.197)
founding date	1838.940	1762.864	1758.106	1679.864	1760.242	1800.331
	(190.087)	(189.051)	(201.612)	(223.937)	(208.273)	(182.545)
proportion of new foreign pupils	0.034	0.030	0.020	0.012	0.024	0.018
	(0.038)	(0.028)	(0.022)	(0.015)	(0.028)	(0.025)
number of schools	67	67	67	66	267	498

*Please see Appendix Table 1 for variable construction

Table 3
Pupils per Teacher

	1988	1995	2000
Private Schools (all ages)	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*

Table 4
Turnover of Students

	Quartiles of Pupil-Teacher Ratio			
	1st quart.	2nd quart.	3rd quart.	4th quart.
pupil-teacher ratio	7.673	8.765	10.068	12.435
	(0.700)	(0.261)	(0.591)	(0.851)
proportion of new post-GCSE students	0.148	0.168	0.135	0.087
	(0.126)	(0.130)	(0.103)	(0.085)
proportion of post-GCSE leavers	0.411	0.336	0.316	0.338
	(0.185)	(0.196)	(0.163)	(0.191)

Table 5: Impact of School and Student Characteristics on Academic Performance in Secondary Schools

Dependent Variable: Grade as a proportion of A-level entries

	Within School Effects			Between and Within School Effects		
	As	A-Bs	A-Cs	As	A-Bs	A-Cs
A-grades as a proportion of GCSE entries	0.467*** (0.063)	0.515*** (0.083)	0.381*** (0.088)	0.728*** (0.047)	0.685*** (0.063)	0.390*** (0.068)
A-Bs as a proportion of GCSE entries	-0.047 (0.069)	-0.068 (0.089)	0.025 (0.096)	-0.066 (0.062)	0.075 (0.089)	0.201** (0.099)
A-Cs as a proportion of GCSE entries	-0.122** (0.061)	-0.050 (0.092)	-0.003 (0.092)	-0.068 (0.051)	0.040 (0.074)	0.213*** (0.079)
ln pupils per teacher	-0.079*** (0.030)	-0.098** (0.043)	-0.097** (0.049)	-0.082*** (0.016)	-0.109*** (0.021)	-0.119*** (0.022)
ln number of students	0.066* (0.038)	0.050 (0.043)	0.021 (0.049)	0.047*** (0.006)	0.070*** (0.008)	0.061*** (0.008)
ln capital spending per pupil				0.009*** (0.003)	0.007* (0.004)	0.004 (0.005)
proportion of teachers who are graduates	0.008 (0.060)	0.151** (0.074)	0.164** (0.075)	0.008 (0.030)	0.061 (0.043)	0.085* (0.044)
teacher turnover	0.089* (0.047)	0.054 (0.070)	-0.021 (0.071)	0.061* (0.036)	0.129** (0.055)	0.117** (0.056)
boys				-0.057 (0.041)	-0.047 (0.054)	-0.056 (0.057)
girls				0.008 (0.019)	0.009 (0.025)	-0.006 (0.028)
proportion of boys in 6th form	-0.014 (0.042)	-0.016 (0.059)	-0.038 (0.058)	-0.018 (0.020)	-0.040 (0.026)	-0.086*** (0.028)
proportion of male teachers				0.058 (0.026)	0.059* (0.035)	0.040 (0.040)
proportion of male teachers x boys school				0.074 (0.047)	0.073 (0.060)	0.099 (0.065)
proportion of male teachers x girls school				-0.011 (0.048)	0.002 (0.072)	-0.080 (0.075)
proportion of boarding pupils	0.001 (0.046)	-0.038 (0.060)	-0.033 (0.062)	-0.039*** (0.008)	-0.024** (0.011)	-0.008 (0.012)
proportion of new foreign pupils	-0.030 (0.109)	-0.062 (0.134)	-0.215 (0.140)	0.095* (0.053)	0.124* (0.073)	0.017 (0.085)
proportion of new post-GCSE students	-0.038* (0.021)	-0.042 (0.027)	-0.059** (0.029)	-0.001 (0.013)	0.014 (0.016)	0.033** (0.017)
proportion of post-GCSE leavers	0.039** (0.019)	0.048* (0.025)	0.074*** (0.027)	0.007 (0.011)	-0.003 (0.016)	-0.011 (0.017)
year dummies	4	4	4	4	4	4
F-statistics	12.96***	7.35***	6.13***	6.4***	4.12***	2.91**
school dummies	266	266	266			
F-statistic	25.34***	39.99***	41.76***			
number of observations	1233	1233	1233	1233	1233	1233
R-squared	0.879	0.887	0.881	0.772	0.772	0.751

Errors reported in parentheses are robust (White) standard errors. All regressions include a constant.
*, ** and *** indicate significance at the 10%, 5% and 1% levels respectively.

Table 6
Impact of School and Student Characteristics on Academic Performance
Boys and Girls Schools
Dependent Variable: A-Cs as a proportion of A-level entries

	Boys' Schools		Girls' Schools	
A-grades as a proportion of GCSE entries	0.266** (0.116)	0.304*** (0.110)	0.598*** (0.197)	0.637*** (0.131)
A-Bs as a proportion of GCSE entries	-0.005 (0.165)	0.314** (0.158)	-0.145 (0.202)	-0.111 (0.182)
A-Cs as a proportion of GCSE entries	0.116 (0.132)	0.229* (0.130)	-0.153 (0.309)	0.159 (0.202)
ln pupils per teacher	-0.062 (0.074)	-0.132*** (0.034)	-0.077 (0.060)	-0.077* (0.046)
ln number of students	-0.036 (0.083)	0.072*** (0.014)	-0.008 (0.077)	0.080*** (0.019)
ln capital spending per pupil		0.009 (0.007)		0.000 (0.011)
proportion of teachers who are graduates	0.187 (0.150)	0.032 (0.072)	0.182 (0.122)	0.169* (0.101)
teacher turnover	0.027 (0.092)	0.083 (0.089)	-0.002 (0.115)	0.221** (0.093)
proportion of boys in 6th form	-0.066 (0.094)	-0.078* (0.047)	1.097 (1.653)	3.307*** (0.939)
proportion of male teachers	0.019 (0.137)	0.086 (0.071)	-0.327 (0.244)	-0.099 (0.077)
proportion of boarding pupils	-0.030 (0.085)	-0.010 (0.017)	0.050 (0.136)	0.059** (0.028)
proportion of new foreign pupils	0.021 (0.299)	0.462*** (0.174)	-0.537 (0.353)	-0.518*** (0.194)
proportion of new post-GCSE students	-0.062* (0.037)	0.012 (0.030)	-0.095 (0.083)	0.073 (0.056)
proportion of post-GCSE leavers	0.061 (0.034)	-0.011 (0.030)	0.095 (0.060)	0.009 (0.044)
year dummies F-statistic	4 4.97***	4 1.49	4 1.75	4 1.40
school dummies F-statistic	117 26.32***		70 7.01***	
number of observations	513	513	329	329
R-squared	0.936	0.805	0.784	0.642

Errors reported in parentheses are robust (White) standard errors. All regressions contain a constant.
*, ** and *** indicate significance at the 10%, 5% and 1% levels respectively.

Appendix Table 1: Variable Descriptions

Name of Variable	Explanation
Number of A-level entries	The total number of candidate-subjects for which a school submits entries at A-level in a particular year.
Number of GCSE entries	The total number of candidate-subjects for which a school submits entries at GCSE level in a particular year.
A-grades as a proportion of A-level entries	The number of A grades as a proportion of the number of A-level entries.
A-grades as a proportion of GCSE entries	The number of A grades as a proportion of the number of GCSE entries.
A-Bs as a proportion of A-level entries	The total number of A and B grades as a proportion of the number of A-level entries.
Other performance variables are similarly defined.	
Number of A-level candidates	The total number of candidates who take one or more A-level subjects in a particular year.
Number of GCSE candidates	The total number of candidates who take one or more GCSE subjects in a particular year.
Number of pupils	The total number of pupils at the school.
Number of 18 year olds	The total number of students whose age on August 31st before the school year started was 17.
Number of 16 year olds	The total number of students whose age on August 31st before the school year started was 15.
Proportion of pupils aged under 11	The proportion of pupils whose age on August 31st before the school year started was under 11 (generally the cut-off point for secondary schools).
Proportion of boarding pupils	The proportion of pupils who are boarders or weekly-boarders, measured at age 14.
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.
Proportion of teachers who are graduates	Total full-time teaching staff who are college or university graduates, divided by all full-time teaching staff.
Proportion of male teachers	Number of male full-time teachers divided by all full-time teachers
Teacher 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 of boys in 6th form	The number of boys in the 6th form divided by the number of pupils in the 6th form.
Proportion of new post-GCSE students	The number of students entering post GCSE in the previous year as a proportion of the number of 16 year olds two years prior
Proportion of post-GCSE leavers	The absolute value of the difference between the number of 18 year olds and the number of 16 year olds minus the number of students entering post GCSE in the previous year, expressed as a proportion of the number of 16 year olds two years prior.
Founding date	The year the school was founded.
Proportion of new foreign pupils	The number of new foreign pupils (permanent homes outside UK) as a proportion of total number of 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.

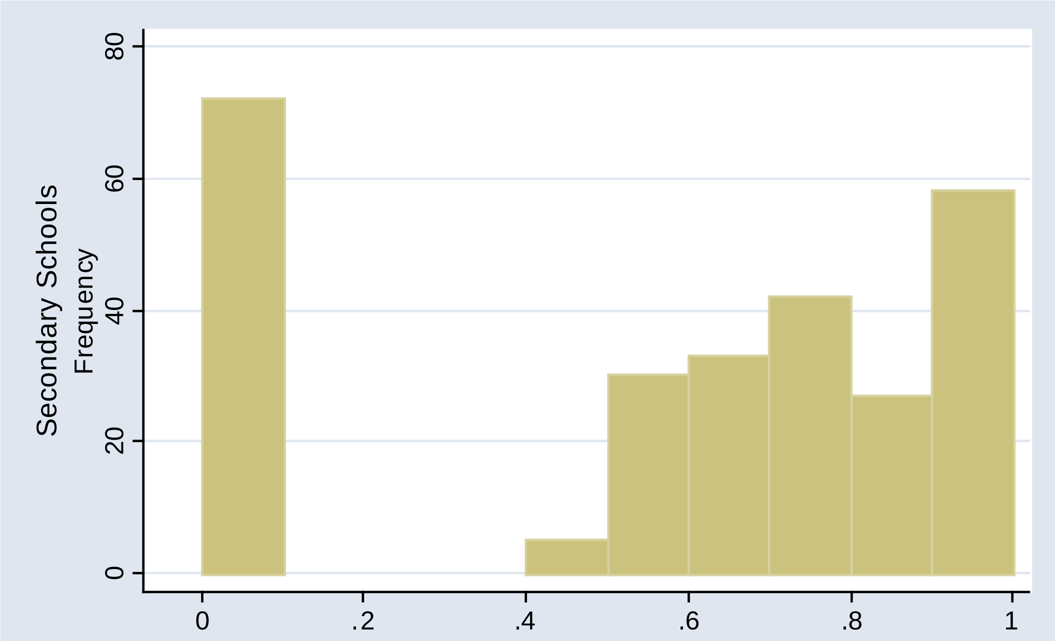

Figure 1:Gender Distribution of Sixth-Form Students

Proportion of boys in the Sixth Form