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ESTIMATING THE RELATIONSHIP BETWEEN SCHOOL RESOURCES AND PUPIL ATTAINMENT AT KEY STAGE 3

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EXECUTIVE SUMMARY

One of the most important questions in education research, at least from a policy perspective, is whether increasing the level of resourcing in schools will lead to improved student outcomes. This study considers this question in the context of students' attainment at Key Stage 3 in English secondary schools.

Specifically the study set out to answer the following research questions.

1. What is the impact of a marginal change in overall resourcing on pupil attainment?
2. What is the impact of extra resources on pupils who differ by gender, ethnicity, poverty and ability and in schools with different mixes of students?
3. What is the impact of extra resources at school level for pupils with SEN?
4. What is the impact of differences in resource mix on pupil attainment?

The main findings from this study are that there are indeed positive marginal resource effects on attainment but they are rather small and subject-specific. Resources appear to have a small but significant impact on pupil attainment in KS3 mathematics and science but little impact on attainment in English. The gain in attainment from additional resources appears to be greater for pupils from poorer home backgrounds. Also, there is some weak evidence that middle ability pupils benefit from additional spending more than pupils in the top or bottom ability quintiles. High ability pupils from low-income families also benefit more from higher resourcing, particularly in science. From a policy perspective, the findings suggest that rather than spreading additional resources evenly across all students, it would be more effective if it were targeted at maths and science and at students who are of average ability or from poorer backgrounds, particularly if they have high ability.

Data and estimation methods used in the KS3 study

The data sources used are the Pupil Level Annual Schools Census (PLASC) database, which has been collected since 2002, and Section 52 data on individual schools' revenues and expenditures, submitted to the DfES by local education authorities. This was supplemented with data on local authority funding and political control.

PLASC provides data on individual pupils' attainment at KS3 in 2003 and prior attainment at KS2 in 2000, enabling a value-added model to be estimated. It also includes a wide range of pupil characteristics, such as gender, SEN category, ethnicity, English as a first language, age and eligibility for free school meals. In addition, it contains data on pupils' post-codes. Using these post-codes, we were able to obtain additional census data on socio-economic indicators of the areas in which the pupils live. This gave us an even richer description of the socio-economic background of each pupil and their neighbourhood.

The study focused on three main resource variables: expenditure per pupil, the average pupil teacher ratio in the school and the ratio of pupils to non-teaching staff. Differences in input costs in different areas mean that a given sum of money buys fewer inputs in high cost areas than in low cost areas. To remove such differences, expenditure per pupil was deflated by a measure of relative area input costs.

In addition to the resource variables, the data contain a large number of variables describing the context of the school (size, proportion of pupils eligible for free school meals, with additional educational needs, boy or girl only school). It also contains information on school type; i.e. age range, selective, denominational, and particular school categories in receipt of additional funding, such as specialist schools, Excellence in Cities, Leading Edge, in Special Measures etc.

The data were assembled for the three years the pupils had been in secondary school, from 2000/1 to 2002/3 and averaged over the three years. The dataset contains around 3000 secondary schools and over 430,000 pupils.

Methodological issues

One of the main objectives of this study was to address some of the significant methodological difficulties inherent in assessing the impact of resourcing on student outcomes. Research on the education production function has been going on since the 1960s but there is still considerable controversy in this largely US dominated literature as to whether additional resources actually do have a positive impact on students' attainment. If it is genuinely the case that additional resources do not improve student outcomes, this implies that there is little point in increasing the general level of funding for schools unless policy simultaneously reforms incentive structures to make schools more efficient. However, this would be an erroneous conclusion if, as is often argued, most of the studies in this research field have suffered from significant methodological problems.

Perhaps the most crucial methodological difficulty in this area of work is that the level of resources per pupil often depends on the pupil's attainment. In other words, the causal relationship between resources and attainment runs in both directions. The dependency of resources on pupil attainment can arise for a number of reasons. The major one in England is that local education authorities (LEAs) allocate additional per student funding to schools with higher concentrations of socially disadvantaged pupils and pupils with learning difficulties. Some Department for Education and Skills Standards Funding is also compensatory in this manner. This results in an inverse correlation between resources per pupil and attainment. When this exists, a straightforward multiple regression of attainment on a set of variables, which includes resources per pupil, is likely to find either that more resources are associated with lower attainment or that there is no statistically significant relationship at all.

This study attempts to overcome this 'endogeneity' problem with the use of various econometric techniques, and specifically with the application of an Instrumental Variables methodology. Full technical details are given in the report. Here we merely note that our results are robust to the methodology used.

The impact of a marginal increase in resourcing per pupil on KS3 attainment

In both the ordinary least squares (OLS) and Instrumental Variables (IV) specifications we found that expenditure per pupil had a statistically significant positive effect on KS3 attainment in maths and science. Consistent with this, a reduction in the pupil teacher ratio had a statistically significant positive effect on maths and science attainment. The effects on attainment estimated using instrumental variables were up to 10 times those from the OLS regressions. In other words, once we allow for the methodological difficulty of endogeneity, discussed earlier, the real impact of resources on pupil attainment is much greater. This confirms that studies that do not take account of the fact that lower attaining pupils receive additional resources (compensatory funding) will considerably underestimate resource effects.

However, expenditure per pupil and the pupil teacher ratio do not appear to impact on pupil performance in KS3 English. This may be due to the larger impact of home background and family linguistic ability on English attainment and the greater importance of the quality of formal learning for maths and science attainment. We also found some effect of reducing the number of pupils per non-teaching staff on attainment in science and English, but these results are very sensitive to the way the estimating model is specified.

However, the estimated resource effects are small, particularly so for non-teaching staff. Spending £100 more per pupil (ceteris paribus) would raise maths and science attainment at KS3 on average by 0.04 of a level. Reducing the pupil teacher ratio by one for the whole school would raise maths attainment at KS3 by just under 0.1 of a level and science by 0.12 levels. These estimates indicate the size of the effects from marginal changes in resources per pupil. It would be unwise, however, to extrapolate the relationship between resources and outcomes to large changes from current resourcing levels. So one obviously cannot conclude that halving expenditure in schools or ceasing to employ English teachers at all would have no effect on pupils' attainment in English.

The effects of resourcing on different groups of pupils

There were no differences in the effect of resources on the attainment of boys or girls, nor between different ethnic groups or for pupils with SEN. Resources did however seem to have a larger impact on attainment in maths and science for mid-ability pupils (i.e. those in the middle quintiles of ability at KS2) than for pupils in the top and bottom quintiles. The impact of additional resources was also greater for top ability pupils who are eligible for FSM, which is 1 per cent of the sample. This group was the only one to have positive and significant resource effects for English.

The impact of differences in resource mix on pupil attainment

As well as the impact of overall expenditure, the impact of different resource mixes on pupil attainment is also an important research question. This study focuses on differences in the proportions of teaching and non-teaching staff employed per pupil. The latter were classified into two groups, support staff who work directly with teachers and administrative and clerical staff. There is clear evidence that reducing the pupil teacher ratio has a small effect on attainment in maths and science (but again not in English). The effect of an additional £100 spent on reducing the pupil-teacher ratio has a slightly larger effect than a general increase in expenditure per pupil of the same amount. On average £100 spent on reducing the pupil teacher ratio increased KS3 maths by 0.07 and 0.09 levels for science, compared to a £100 increase in overall expenditure per pupil which increased attainment in both subjects by 0.04 levels. We found some evidence that reductions in the non-teaching staff per pupil ratio were associated with very small improvements in attainment in KS3 science and English. Reducing the pupil teacher ratio has more impact on attainment than reducing the ratio of pupils to non-teaching staff. There is also tentative evidence that holding the pupil teacher ratio constant, teacher quality – measured by the relative pay of teachers compared to average earnings - has a positive and significant effect on attainment in all three subjects.

Policy implications

The tentative policy conclusions emerging from this study are that there are indeed positive marginal resource effects on attainment but they are rather small and subject specific. They are evident for maths and science but not so for English with respect to expenditure and the pupil-teacher ratio. The marginal resource effects tend to be stronger for pupils from poorer home backgrounds. Also, there is weak evidence that middle ability pupils benefit from additional spending more than pupils in the top or bottom quintiles. High ability pupils from low-income families also benefit more from higher resourcing. The evidence on the attainment effects of the pupil teacher ratio and relative teacher pay suggests policy-makers should direct expenditure to maintaining good quality teaching staff in relation to pupil numbers. However, due to lack of data, we did not investigate the relationship between the actual pupil staff ratios and class sizes at subject level. Our conclusions would be more persuasive if we had evidence for class size effects on subject attainment and better measures of teacher quality related to pupil attainment. As has been said, one can interpret these findings as indicating that resources need to be targeted where additional resources are likely to have a positive impact.

This research demonstrates the progress that can be made in education production function research for English schools when using improved datasets, which potentially enable the problem of endogenous resources to be addressed. This study also shows how misleading results can be when proper account is not taken of the methodological difficulties inherent in this field of research. The evidence from this study suggests that targeting resources at specific curriculum areas and particular groups of students gives relatively higher effects on attainment than a general overall increase in spending. This implies that policy-makers should concentrate increased spending on projects targeted at specific student groups or curriculum areas. To avoid the methodological problem of resources depending on student attainment when evaluating the outcomes of such additional spending, control groups are needed to create exogenous variation in resourcing.

1. INTRODUCTION: RESEARCH FOCUS

There is still considerable controversy in the literature as to whether in developed countries additional resources have a positive marginal impact on students' learning outcomes (Hanushek, 1979, 1986, 1997; Krueger, 2003; Laine et al., 1996; Levačić and Vignoles, 2002). Hanushek's conclusions from reviewing 90 US studies are much quoted:

> there is no strong or consistent relationship between school resources and student performance. In other words there is little reason to be confident that simply adding more resources to schools as currently constituted will yield performance gains among students. (Hanushek, 1997 p. 148)

However his method for selecting and interpreting studies for review has been criticised by some US researchers who have provided contrasting evidence of a positive relationship between resources and students' learning outcomes (e.g. Laine, Greenwald and Hedges, 1996; Krueger, 2003).

There is a theoretical rationale for not observing significant and positive marginal resource effects on student outcomes, namely that schools are not efficient. The argument is that schools are inefficient because they lack the motivation or knowledge to optimise students' learning outcomes, given the school's budget constraint, the technology by which inputs and outputs are related and the relative prices of inputs. Alternatively, the failure of many studies to identify any significant positive resource effects on learning outcomes may be due to methodological problems in estimating education production functions. In the absence of experimental data, it is difficult to create or observe exogenous variation in schools' resources. This leads to a problem of endogeneity in school resources, whereby resources depend on student attainment as well as student attainment depending on resources. This problem is particularly acute when researchers have to rely on data from natural settings to estimate education production functions. Estimation problems are often further confounded in such studies by poor model specification.

A review of the somewhat sparse UK literature on education production functions, commissioned by the DfES (Vignoles et al., 2000), found only a few studies that were methodologically sound, in that they used pupil level data on attainment, school level resourcing variables and made some attempt to address the endogeneity issue. Apart from a recent class size study (Blatchford et al., 2002) all these higher quality studies used pupil level data from the NCDS (National Child Development Study). Vignoles et al (2000) concluded that these studies had found some small but statistically significant positive effects from school resource variables on educational outcomes. Three of the NCDS studies found some evidence of a positive effect from school resource variables on attainment (Dearden et al., 2001; Dolton and Vignoles, 2000; Dustmann et al., 2003), and Dearden et al. found an effect on wages. Another NCDS data study (Iacovou, 2002)[1] found smaller class size improved maths scores at aged 7 for all pupils, and reading and maths scores for girls at age 11. Generally in these studies fewer school resource variables were reported as significant when a larger number of explanatory variables was included, indicating that omitted variables bias is likely to be a problem. Identifying differential effects of resources for different types of student also emerged as an important avenue for further investigation. In this report we attempt to address both these issues.

A drawback to NCDS studies is that the evidence on resource effects on school outcomes relates to the 1970s. Other studies have used more recent school level data and not found any resource effects (Bradley and Taylor, 1998). This study aims to estimate an education production function using the more extensive data now available from the Pupil Level Annual Census of Schools (PLASC), combined with data on school level revenue and expenditure from Section 52 Statements submitted by LEAs (Local Education Authorities), as well as additional data on LEA education grants and political control. The purpose of the study is to establish whether a positive marginal impact of resources on pupil attainment in English, maths and science at Key Stage 3 can be found[2]. The study has the advantage of including a large number of pupil level variables and being able to attempt to correct for endogeneity by using suitable instrumental variables. More precisely, the study addresses the following research questions, which are derived from an earlier pilot study funded by the Value for Money Unit on Resources and Pupil Attainment (PriceWaterhouseCoopers and Institute of Education, 2003).

1. What is the impact of a marginal change in overall resourcing on pupil attainment?
2. What is the impact of extra resources on pupils who differ by gender, ethnicity, poverty and ability and in schools with different mixes of students?
3. What is the impact of extra resources for pupils with SEN?
4. What is the impact of differences in resource mix on pupil attainment?

In addition the dataset assembled for this study enable us to test the relationship between student attainment and several other variables that have not been extensively investigated in other studies. These are a measure of school competition and socio-economic indicators of the neighbourhoods in which the school's pupils live.

In the next section of the report we discuss estimation issues – the form of the model being estimated and our approach to selecting the instrumental variables. Since resourcing variables are potentially endogenous, in section 3 we outline how school funding in England is determined. We discuss compensatory funding for socially disadvantaged pupils, which is the main potential source of endogeneity. Section 4 summarises the data used in the study. Section 5 presents the results of school level regressions of per pupil resourcing. We have two main resource variables – revenue per pupil and pupils per staff. The latter is subdivided into pupils per teacher and pupils per non-teaching staff. The regressions in section 5 serve two purposes. They improve our understanding of how these resource variables are determined at school level and also suggest some potential instrumental variables for the estimation of resource effects on pupil attainment. Section 6 presents the first stage of the analysis of pupil attainment in the three subjects taken at KS3 – maths, science and English – using OLS (ordinary least squares) estimation. We find positive, significant but very small resource effects for maths and science and none for English.

In section 7 we report estimations using instrumental variables (IV) – where the instruments are variables measuring the party political control of the local education authority (LEA) and lagged school size (the number of full-time equivalent pupils in 1999). We find that in the IV regressions, revenue per pupil and the pupil teacher ratio have correctly signed (i.e. positive for revenue per pupil and negative for the pupil teacher ratio) and significant effects on KS3 maths and science, and that this effect is up to 10 times larger than those observed in the OLS estimates. Nonetheless, even the IV estimates of the effect of resources are still quite small in practical terms. We do not find effects from revenue per pupil or the pupil teacher ratio on KS3 English test scores for most pupils. Section 8 briefly discusses the effects of key non-resource variables on student attainment, such as our measure of school competition. Further analyses of whether resources have differential effects for pupils with different characteristics (gender, ethnicity, ability, poverty and SEN) are reported in section 9. Resources per pupil appear to have a larger impact on the maths and science attainment of pupils who are eligible for free school meals and possibly for those in the middle ability bands. Section 10 considers the policy implications of these findings and section 11 draws together the overall conclusions of the study.

2. ESTIMATION ISSUES

The education production function is specified in a general form:

$Q_{sijk} = f(X_{jk}, V_{ijk}, C_{jk}, L_k)$

Where

Q_{sijk} = attainment in subject s of student i in school j in LEA k

X_{jk} = vector[3] of school resources per pupil at school j in LEA k

V_{ijk} = vector of pupil characteristics of pupil i at school j in LEA k

C_{jk} = vector of school level variables indicating school type, age range, pupil composition etc

L_k = vector of Local Education Authority variables for all schools in LEA k

The linear form of the equation estimated is given by:

$Q_{sijk} = \alpha + \beta X_{jk} + \gamma V_{ijk} + \delta C_{jk} + \theta L_k + e_{sijk}$

where e_{sijk} is the random disturbance term at pupil level.

In the literature the Cobb Douglas form of the education production is often specified (e.g. Mayston, 2002):

$Q = AX^{\beta}V^{\gamma}C^{\delta}L^{\theta}e$

This is linearised by taking logs. The advantage of the Cobb-Douglas form is that the estimated coefficients β, γ, δ, θ, are constant elasticities (e.g. β, the proportional change in attainment due to proportional change in resourcing, is the same at all levels of attainment and resourcing), whereas the elasticities in the linear form vary with values of the variables. However, the linear form has the advantage in this study of coefficients that are easier to interpret. We can produce estimates of the change in KS3 attainment measured in fractions of a level due to increasing spending by £100, for example, or from reducing the pupil-teacher ratio by one pupil. We therefore estimated the linear version of the model and report results from these estimations. In addition the model was estimated in log linear form for all pupils in the dataset and these results are reported briefly in section 7.

2.1 Clustering

Since our data set consists of students nested in schools which are in turn nested in LEAs we have a hierarchical dataset with three levels – pupil, school and LEA. If being in the same school has a common effect on the attainment of its students the attainment of two pupils in the same school will be more alike than that of two randomly selected pupils. If this correlation between the attainment of pupils in the same school is not explained by school level explanatory variables in the model, the error terms of the students in the same school will be correlated. In addition, there may be correlation between the mean attainment of schools in the same LEA, which is not adequately explained by including LEA variables. When the independence assumption is violated OLS estimation yields lower standard errors for the estimates than would be the case if the effect of clustering on the standard errors were taken into account. Consequently there is a risk that OLS estimators are statistically significant whereas with the corrected larger standard error the estimators are not significant. The clustering problem with respect to standard errors can be avoided by use of appropriate statistical procedures, which when calculating the standard errors take account of clustering. All regressions reported in this study have accounted for such clustering. In the main part of the study we have undertaken the estimation in Stata because this statistical software has standard procedures for estimation with instrumental variables.

As an extension to the study a multilevel model was estimated in MLwiN. The multilevel model assumes that there are different random errors at LEA, school and pupil level whereas the model estimated in Stata has a random error term only at pupil level.

2.2 Endogeneity

As has been said, the problem posed by the endogeneity of resources arises because resources are not randomly distributed across students and schools. Instead resources may be distributed more systematically across the system, and partly on the basis of pupil or school educational performance. If poorer performing schools are given more resources this will tend to hide any potentially positive relationship between additional resources and educational performance.

There are a number of different ways in which resources are distributed systematically across the education system, making resource variables endogenous. Firstly, central government and LEAs distribute resources partly on the basis of the needs of different pupils and schools. Thus schools in more deprived areas or with a greater number of students with special education needs will have higher levels of resourcing per student. These schools may well also have lower performance levels, hiding the true relationship between resourcing and outcomes. Another source of endogeneity stems from the behaviour of the so-called ‘producers’ in the system, i.e. teachers and head teachers. For example, head teachers and teachers may gain more job satisfaction from teaching in better-resourced or better performing schools (or both). Thus the ‘best’ teachers and head teachers will compete to get the ‘best’ jobs at these better resourced/ better performing schools. Since these teachers/ head teachers are more effective they will improve student performance. This too will affect the underlying relationship between resourcing and school performance. Similarly, consumers – parents and their children – make decisions on school choice partly on the basis of resourcing and school performance. If parents who have greater interest in their children’s education, or whose children are better motivated learners, systematically choose better resourced schools then again what we observe as a positive relationship between higher school resources and better student outcomes may actually be due to better students choosing better resourced schools.

All this is to say that as well as modelling the relationship between resourcing and pupil attainment, so we also need to consider the determinants of resourcing levels. We therefore include a second equation in the model, which expresses each resource variable, X_{rijk}, as a function of its determinants at pupil, school and LEA level (r denoting the type of resource input)

$$X_{rijk} = g(V_{ijk}, C_{jk}, L_k)$$

The per pupil amount of resourcing a school receives depends on variables at school level such as school size, age range, school type and indicators of social deprivation and learning needs of the schools’ pupils. The LEA level variables that are assumed to determine resources per pupil are the political party control of the local authority in the year of budget setting and the standard spending assessment per secondary pupil, which is a measure of the LA's need to spend on secondary pupils used by central government for determining the Revenue Support Grant received by each local authority (Office of the Deputy Prime Minister, 2002). In order to be able to identify (i.e. solve) the attainment equation, some of the variables in the resource equation must be exogenous to attainment (i.e. have zero coefficients in the attainment equation).

We also include pupil level variables in the equation for determining the amount of resourcing received by the individual pupil at school level in order to reflect the influence of factors determining choice of school by families. For example parents of higher attaining pupils may avoid schools with high concentrations of students eligible for free meals and which consequently receive higher funding per pupil.

Because school resourcing per pupil may vary both positively and inversely with student attainment, the direction and magnitude of the potential endogeneity bias in school production functions is not certain a priori. Mayston (2002) developed quite a complex 16 equation structural model of the interactions between parental choice of school, pupil numbers and school funding and concluded that there is likely to be a cumulative negative bias on the resource variable.

There are two main ways of dealing with endogeneity in non-experimental data (discussed in the report to the DfES by Levačić and Feinstein on Approaches to the Evaluation of the Relationship Between School Resources and Student Outcomes). These are:

(1) allowing for a sufficiently large number of pupil level background variables (often estimated using a matching methodology);

(2) finding instrumental variables which explain school resources per pupil but are not correlated with pupil attainment (similar to the approach suggested by Mayston (2002)) .

To achieve (1), it is necessary to include in the regression all pupil background variables that determine educational attainment. PLASC provides some of these variables - gender, age, ethnicity, eligibility for free school meals, English as an additional language, SEN status - but these are still a restricted range. In this study additional pupil background variables were obtained by utilising pupils' home postcode from PLASC to link with Census 2001 data on neighbourhood socio-economic indicators. These indicators include the education levels in the neighbourhood, unemployment rates, the number of single parents and the proportion of the population from an ethnic minority group. These indicators can be interpreted either as proxies for the pupils' own home backgrounds or as capturing the influence of the pupils' neighbourhoods on educational outcomes[4]. The inclusion of census data allows for a wider range of background factors in our estimation, thereby reducing the potential for endogeneity bias.

We also tackled the endogeneity problem by using instrumental variables and looked for variables that determine resources per pupil but are not correlated with pupil attainment. The main form of endogeneity in the English school system is that the per pupil funding a school receives is positively related to indicators of social deprivation, in particular free school meals, which are in turn inversely related to pupil attainment, both at the school and pupil level. Some LEAs also fund according to indicators of prior attainment. To find potential instrumental variables we regressed school revenue and expenditure per pupil on their determinants. The political party in control of the local authority was found to be statistically significant in explaining schools' revenue and expenditure per pupil but is unlikely to be directly related to individual pupils' attainment. We also found school size to be a statistically significant determinant of school revenue and expenditure per pupil but not statistically significant in explaining pupils' attainment. These variables can therefore be used to provide instruments for school expenditure per pupil. School size in the year prior to the pupils entering secondary school was used as the second instrument to reduce further the possibility of correlation with pupil attainment. Discussion of the first stage of the analysis – the determinants of the resource variables – is given below and further details are in Appendices A and B.

3. THE SCHOOL FINANCE SYSTEM IN ENGLAND

Because of the importance of the school financing system for creating endogeneity in the allocation of resources to schools it is necessary to outline its main features. The discretion of the 150 Local Education Authorities in influencing the general level and distribution of funding to the schools they maintain is crucial in providing a source of potential instrumental variables.

Schools on average receive around 90% of their public revenue funding via the local education authority. The rest of public funding comes from the DfES (transmitted via the LEA) mainly from a series of direct grants, which fall within the programme of Standards Funding. Some of these additional grants are due to the school participating in DfES programmes, such as specialist schools and Excellence in Cities.

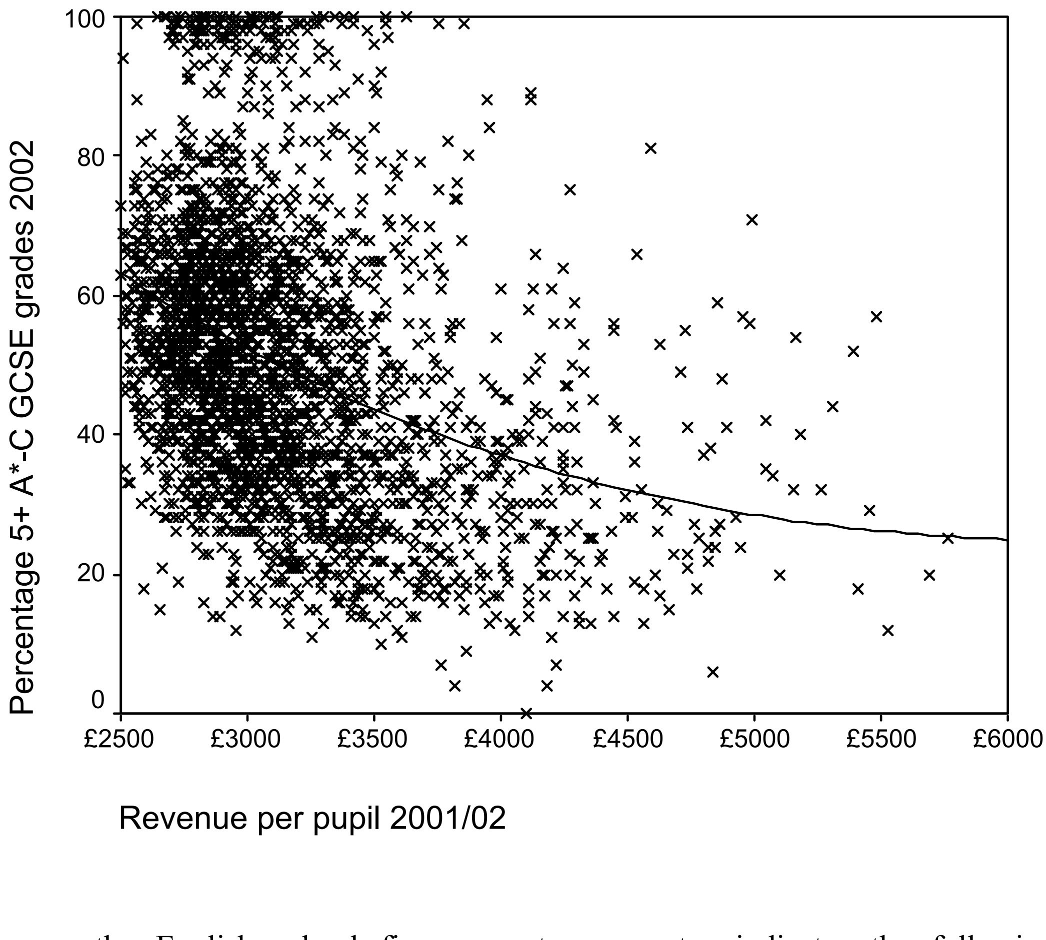
Local authorities receive a block grant from central government, called Revenue Support Grant, which finances about three quarters of their expenditure on services. This grant is calculated by a complex formula, which is intended to reflect the differing needs of local authorities to spend on services. During the period covered by our study, the calculation of local authorities' need to spend was called Standard Spending Assessment (SSA)[5]. Each service, such as education, had its own SSA. Education SSA was split into 5 sub-blocks, one of which was for secondary education (children from the ages of 11-15[6]). SSA is based on three types of factors that affect LEAs' educational costs[7]. One is Additional Educational Need, which is based on LA level indicators of social disadvantage[8]. The second is sparsity defined in terms of numbers of inhabitants per hectare and the third is an Area Cost Adjustment Factor[9] (ACA). This takes account of differences in wages and business rates between areas since both affect costs.

While largely based on SSA, Revenue Support Grant (RSG) is further adjusted for differences in local authorities' fiscal capacity (ability to raise tax revenues). Fiscal capacity for the purposes of RSG calculations is the amount of council tax each local authority could collect if a common notional council tax rate were applied to the value of each authority's residential property tax base. The per capita tax base is indicative of the wealth of the local authorities' residents. If education has a positive income elasticity (i.e. if wealthier individuals and LEAs choose to spend more on education) one would expect tax capacity to have a positive effect on LEA spending per pupil. However, the revenue support grant calculation attempts to neutralise the effect of tax capacity on local authority spending. For a given amount of SSA, revenue support grant is reduced by more, the higher the local authority's tax base. If this adjustment is successful in neutralising the effect of tax capacity on LA spending then the tax base should have no impact on the amount of funding per pupil an LEA allocates to its schools.

LEAs are required to allocate budget shares to schools on the basis of a formula determined by the LEA within guidelines set by government. At least 75% of the LEA's budget allocated to schools must be distributed according to the number and ages of pupils. The amount per pupil is referred to as the Age Weighted Pupil Unit (AWPU). In the period of the study LEAs had[10] discretion in determining the level of funding for schools. The LEA sets the AWPU for each year group. The remaining 25% is allocated within the formula for various factors, which include differences in schools' site costs, an allowance for the higher fixed costs of small schools and various indicators of students' learning need – the most frequently used being the proportion of pupils eligible for free school meals. This too ensures that schools in poorer catchment areas, with potentially lower performing students, will receive additional resources, requiring careful attention to the endogeneity problem when estimating the impact of resources on attainment. Schools also receive, via the LEA, a School Standards Grant from central government, which is a fixed amount related to phase and size of the school. Since 2002/03 all post-16 students in schools have been funded by the Learning Skills Council, which operates its own formula. This formula is mainly driven by the numbers of courses being taken, with weightings for different groups of courses. There is a small element for social disadvantage as well as adjustments to prevent schools experiencing a sudden change in post-16 funding compared to that previously provided by the LEA.

The inverse relationship between schools' revenue per pupil and pupil attainment at GCSE/GNVQ (5 or more A* - C grades) is illustrated in Figure 1.

Figure 1 Relationship between schools' revenue per pupil and attainment at GCSE



The way the English school finance system operates indicates the following hypotheses.

- When local authorities have discretion on how much to spend in total and on each service, the political party control of the authority affects the amount the authority allocates to school budgets and how it is distributed to schools with differing characteristics (e.g. size, social disadvantage). Thus school revenue per pupil is affected by the policies of the political party in control of the LA. Most authorities have a single party control but by 2003 almost one third had 'No overall control' (NOC).

- Since Education Secondary SSA is an indicator of the LA's need to spend on secondary education, it is anticipated to have a positive impact on schools' revenue per pupil.
- Expenditure per pupil, which is determined by schools given delegated financial management, is highly correlated with revenue per pupil.
- Staffing decisions (i.e. how many teachers and different types of non-teaching staff to employ) are determined at school level and will be influenced by revenue per pupil, school size, school type and the learning needs of students as assessed by the school's management.

These hypotheses were investigated first, before proceeding to an analysis of the determinants of KS3 attainment and the affect of the resource variables.

The available data enable us to investigate the effects of overall resources, measured as revenue per pupil adjusted for differences in area costs and the effects of teacher and non-teacher staffing. The relative proportions of overall resources allocated to the main types of input in 2002/3 by secondary schools are shown in Table 1.

Table 1 Secondary school expenditure by type

	Amount per pupil	%
Total income (excluding capital income)	£3,535.53	
Total expenditure (excluding capital expenditure)	£3,531.90	
Total staffing expenditure	£2,781.23	78.8
Teaching staff expenditure	£2,156.90	61.1
Supply teacher expenditure	£102.58	2.9
Education support staff expenditure	£200.37	5.7
Other staff and staffing expenditure	£321.38	9.1
Total learning resources expenditure	£283.64	8.0
Expenditure on other supplies, services and financing	£227.45	6.4
Expenditure on premises and facilities	£239.58	6.8

Source of data CFR returns 2002/2003 from OFSTED (2003) Table 5.1.1a

Note: income and expenditure include Area Cost Adjustment whereas the definitions of revenue and expenditure used in our study remove ACA by dividing through by it.

4. VARIABLES AND DATA

The dataset is extensive, embracing pupil level measures of attainment and other characteristics, school variables (size, social disadvantage, type and resources) and LEA level variables (SSA, political control, teacher salary relative to average earnings). All school census data are collected in January. The financial data refer to financial years (April to March).

The student outcome measures are Key Stage 3 tests in English, maths and science taken in 2003 - sat by pupils towards the end of Year 9 when they are aged 14 to 15. Data for the explanatory variables were assembled for the three years the pupils had been at secondary school prior to taking the KS3 tests[11] – i.e. from 2000/01 to 2002/03 and for the previous year 1999/2000. The KS3 test results are published as levels from 3 to 8. Any result below level 2 for maths or level 3 for English and science is reported publicly for students as N (i.e. not attaining KS3). In PLASC the KS3 and KS2 results are also reported as marks, which provide a finer differentiation and are a continuous measure of the variable. The level measure of KS3 contains only 7 values. Consequently it is not appropriate to treat it as a continuous variable and ordinal regression would be needed. However, it is not possible to use KS3 marks without making adjustments for the different tiers. The marks were therefore recalibrated to make the marks from different tiers equivalent in KS levels, producing marks in fractions of a level. This is explained further in Appendix H.

4.1 Pupil level variables

At the pupil level we control for prior attainment at Key Stage 2 taken at the end of primary school and for a set of personal characteristics listed below. Pupil level variables from PLASC , included as determinants of KS3 test results, are:

Key Stage 2 marks in English, maths and science taken in Year 6, the last year of primary school recalibrated to fractional level equivalents (see Appendix H)

gender

age (measured as number of days born after August 31st 1989)

ethnicity (white, mixed, Asian Indian, Pakistani and Bangladeshi, Asian other, Black, Chinese, not known)

English spoken at home (Yes, No, not known)

special educational needs (none, school action or school action plus, statement of SEN or being assessed)

eligible for free school meals

school attended at time KS3 sat

home post code (this is linked to neighbourhood SES indicators from the census)

socio-economic indicators of census output area of home post code:

proportion of economically active population unemployed

proportion of population which has level 1 or no qualifications

proportion of households with children where there is a lone parent proportion of population of black ethnicity

proportion of population of Chinese ethnicity

proportion of population of Pakistani or Bangladeshi ethnicity

proportion of population of Asian Indian ethnicity

Pupils designated as boarders were omitted.

4.2 School level variables

As students' attainment is also influenced by the school context we control for a range of non-financial variables at school level, which are derived from the Annual Schools Census and Register of Educational Establishments. These are:

pupil roll (i.e. size)

capacity utilisation (pupil roll relative to capacity)

percentage of pupils eligible for free school meals

percentage of pupils with statements of special educational need

percentage of children with ethnic minority backgrounds identified as underachieving used for calculating Additional Educational Needs weighting for 2003/4 Education Formula Spending Share[12].

age range of pupils (lowest statutory age, highest statutory age)

selective intake (comprehensive, grammar, secondary modern)

denominational (non-denominational, C of E, RC, Jewish, other)

mixed or boys or girls only;

participating in government programmes:

Specialist School

Special Measures

Education Action Zone

Beacon Status

Excellence in Cities

EiC City Learning Centre

Fresh Start

Training School

Leading Edge Partnership

Leadership Incentive Grant

Measure of school competition: number of schools within 1km, 2km, 5km and 10km radius[13]

School urban/rural indicator

The only non-financial resource variables we have data on from the Annual Schools Census is staffing. We have various measures of pupils per full time equivalent staff:

- pupils per total teachers
- pupils per qualified teachers
- pupils per unqualified teachers
- pupils per non-teaching staff – subdivided into support staff and clerical/ administrative.

We also include financial resource variables for 1999/2000 to 2002/03 taken from Section 52 Financial Outturn returns made by LEAs to the DfES. These data are for the financial year that runs from April to March. The financial variables are:

- current revenue per pupil[14] (this includes all LEA and DfES sources of revenue excluding balances brought forward from the previous year);
- expenditure per pupil (net of expenditure funded from schools' own revenue sources such as income from catering, parental contributions or income generation).

Middle deemed secondary schools were excluded from the analysis after some exploration of their data. They are excluded because they are funded at a considerably lower rate per pupil than other secondary schools, as they cater for a lower age range. We also included school level lagged GCSE results as a determinant of resourcing variables, which clearly excludes middle schools[15].

School level continuous variables, which vary from year to year, were averaged over the three years the pupils taking KS3 in 2003 were in secondary school i.e. from 2000/01 to 2002/03. Including the three year average for the continuous variables rather than three separate values removes the problem of the high degree of multicollinearity between the three year values of each variable if included separately. The average three year value for the resourcing variables reflects the total amount utilised over the three years the pupils were in secondary school.

4.3 LEA level variables

LEA level variables are included because some are determinants of schools' revenues and others because they affect schools' labour costs. The variables included are:

- Standard Spending Assessment for secondary education per pupil
- political party in control of the LEA in the year of budget setting
- teachers' pay relative to average gross full-time weekly earnings at local authority level[16].

Standard Spending Assessment and teachers' relative pay were also averaged over the three years 2000/1 to 2002/3.

Summary statistics for the variables used in our analyses are listed later in the Report in Table 6.

5. ANALYSIS OF RESOURCE VARIABLES

The first stage of the analysis was to investigate the determinants of the resource variables in order to find out the extent to which school resources are endogenous (dependent on factors relating to pupils' attainment) and whether they also have statistically significant exogenous determinants which could be used as instrumental variables. School resources fall into two types: financial and staffing variables. These are discussed in turn.

5.1 Finance Variables

The finance variables are revenue per pupil, which is the amount the school received from state sources (via the LEA and DfES) and expenditure per pupil - the amount the school actually spent in the financial year, excluding spending financed out of own income. Expenditure and revenues from non-state sources are excluded for three reasons. First, schools' own generated revenues are only available for 2002/3 and not for earlier years. Second, some of schools' own income is not spent on education but on non-educational services such as catering. Third, there are likely to be greater inconsistencies in schools' reporting of own income than of public revenues. The measure of school revenue we use in the analysis is 'total current public resources available to the school minus balances brought forward'. Expenditure is total current expenditure net of schools' own income. Revenue and expenditure per pupil were adjusted for differences in area input costs by dividing by ACA (area cost adjustment[17]). This is done to take account of the fact that £1000 per pupil in a high cost area is worth less in terms of the inputs it can purchase than in a low cost area. ACA is a readily available index of area costs and is also used in calculations of local authorities' standard spending assessment. The SSA measure was also divided by ACA to be consistent with the adjustment to revenue and expenditure per pupil.

Given the way schools are funded, we expect that secondary schools' revenue per pupil is in part determined by LEA funding policies, the LEA's standard spending assessment for secondary pupils and DfES Standards Funding, which include a number of specific programmes for which some schools qualify (e.g. Excellence in Cities, Leadership Incentive Grants). While it is school expenditure rather than revenue that is more closely related to the level of real resources allocated to teaching and learning, expenditure and revenue are highly correlated (0.96).

So we regress both school revenue and school expenditure per pupil on the same set of regressors. The school resource variable regressions were run in Stata, which as has already been said, has procedures for correcting standard errors for the effects of outliers and of schools being clustered in LEAs. A few schools, which were extreme outliers as they had revenue per pupil in excess of £5000 or less than £2000 per annum, were omitted.

Table 2 presents the regression results for the financial variables in summary form, showing just the direction of the relationship and whether the coefficients are significant at 10% or less. Table 2 summarises the results for regressors which are related to student attainment – namely the percentage of students eligible for free school meals and SEN (pupils with statements). Capacity utilisation is also related to attainment at school level (the correlation is .33). School size is inversely and non-linearly related to revenue per pupil as one would expect since smaller schools have a higher proportion of fixed to variable costs. Also shown in Table 2 are the potential instrumental variables, Standard Spending Assessment per secondary pupil, political party in control of the council in the year of budget setting and school size (in terms of the pupil roll). Included in the regressions but not shown in Table 2 are 24 dummies representing different types of school (by gender, selection, lowest age of pupils, governance, and government programme attracting additional funding). The full set of results is given in Appendix A.

The estimation results confirm that revenue and expenditure per pupil are endogenous. They are inversely related to lagged GCSE attainment in 2002/3 and to capacity utilisation, and are positively related to FSM and SEN. (The percentage of pupils with Additional Educational Needs was insignificant and so not included in the final regressions.) Standard Spending Assessment is positive and significant in 4 out of 6 regressions. Conservative Party control is inversely related to revenue/expenditure per pupil in 2 of the 3 years.

The regressions for revenue and expenditure per pupil indicate that party political control, SSA per secondary pupil and school size are potential instrumental variables for the analysis of resource effects on pupil attainment. This analysis is reported in Section 7.

Table 2 Summary of key results from regressions of revenue and expenditure per pupil (shows direction of relationship; is significant at 10% or less unless otherwise stated)

	Revenue per pupil			Expenditure per pupil		
	2002/3	2001/2	2000/1	2002/3	2001/2	2000/1
Pupil roll	Inverse, non-linear	Inverse, non-linear	Inverse, non-linear	Inverse, non-linear	Inverse, non-linear	Inverse, non-linear
% SEN	Positive, non-linear	Positive, non-linear	Positive, non-linear	Positive, non-linear	Positive, non-linear	Positive, non-linear
% FSM	Positive, non-linear	Positive, non-linear	Positive, non-linear	Positive, non-linear	Positive, non-linear	Positive, non-linear
Capacity utilisation	Inverse	Inverse	Inverse	Inverse	Inverse	Inverse
SSA	Positive	Positive	Positive	Positive	Insignificant	Insignificant
Conserv.	Insignificant	Inverse	Inverse	Insignificant	Inverse	Inverse
Liberal	Insignificant	Insignificant	Insignificant	Positive	Insignificant	Insignificant
No overall control	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Lagged GCSE	Inverse	Insignificant	Insignificant	Inverse	Insignificant	Insignificant
R squared	0.75	0.74	0.73	0.73	0.68	0.65

5.2 Staffing variables

The main categories of staff distinguished in the analysis are teachers and non-teaching staff. Teachers are divided in the Annual Schools Census into qualified and unqualified. The latter classification contains the following categories:

instructors and student teachers

foreign language assistants

teachers entitled to qualify by service

teachers not recognised as qualified

graduate and registered teachers on Graduate/Registered Teacher Scheme (including those on Licensed or Overseas Trained Teacher Schemes).

Given these categories of unqualified teachers, it is not necessarily the case that a school with a higher unqualified to qualified staff ratio is in any sense worse staffed than one with a lower ratio. The higher ratio can be due to employing foreign language assistants rather than a large proportion of ineffective, unqualified teachers. The ratio of unqualified to qualified teachers varied considerably between schools between 80% at one extreme and zero for 744 schools in 2000/1, 524 in 2001/2 and 427 in 2002/3. Therefore to include only qualified teachers in the analysis of teachers could give a misleading impression of low teacher staffing in some schools. For this reason the analysis focuses on total teachers.

Non-teaching staff is subdivided in our analysis into two categories - support staff, and administrative and clerical staff. Support staff are those who work directly with pupils and consist of:

special needs support staff

ethnic minority support staff

FTE qualified and unqualified teaching assistants

technicians

other education support staff (child care staff, nurses, matrons, other medical staff, librarians and others).

As staffing decisions are taken at school level the staffing variables were regressed on revenue per pupil and not SSA and party political control, the effects of which are taken into account through revenue per pupil. The school type dummies that were insignificant were not included in the final regressions of the staffing variables. We report regression results for three sets of staffing variables, measured as pupils per staff. Hence a negative sign on a regressor indicates that it is associated with more staffing per pupil. The three staffing measures for which regressions were run are:

pupils per teacher (PTR)

pupils per support staff (PPSS)

pupils per administrative and clerical staff (PPACS)

The results are presented in broad summary form in Tables 3 to 5 for the years 2002/3, 2001/2 and 2000/1. The results in full for the most recent year, 2002/03 are to be found in Appendix B. As expected, revenue per pupil reduces pupils per staff for all types and does so at a decreasing rate. Larger schools employ fewer teachers and administrative staff per pupil but size has no effect on support staff per pupil. A higher proportion of students with SEN is associated with fewer pupils per teacher and per support staff but has no effect on administrative and clerical staffing per pupil. Schools with higher capacity utilisation employ fewer teachers and administrative staff per pupil (ceteris paribus). Higher percentages of AEN students are associated with lower pupil teacher and pupil/admin staff ratios. The most interesting relationship is that between lagged GCSE results and staffing ratios. Schools with higher attainment, given revenue per pupil and other variables, employ more teachers per pupil but fewer support staff and admin staff per pupil. These findings confirm that staffing choices are endogenous. The quantity of staff per pupil depends on revenue per pupil, which is endogenous. Holding revenue per pupil constant, schools with different levels of attainment and social disadvantage choose slightly different staffing ratios for teachers, support staff and admin staff.

Table 3 Summary of regression results for pupil teacher ratio

	2002-3		**2002/01**		**2000/01**	
Explanatory variable	**Direction of relationship**	**Stat. signif-icance**	**Direction of relationship**	**Stat. signi-ficance**	**Direction of relationship**	**Stat. signi-ficance**
Number of FTE pupils	PTR rises as schools size increases at a decreasing rate	At 1%	PTR rises as schools size increases but at a decreasing rate	At 1%	PTR rises as schools size increases but at a decreasing rate	At 1%
Percentage of SEN students	PTR falls non-linearly as SEN increases	At 5%	PTR falls non-linearly as SEN increases	At 5%	PTR falls non-linearly as SEN increases	At 5%
Percentage of pupils eligible for FSM		Not signif-icant.		Not signify-cant.		Not signify-cant.
Capacity utilisation	PTR rises	At 10 %	PTR rises	Not sig	PTR rises	Not signify-cant.
Sixth form	Lower PTR	At 1%	Lower PTR	At 1%	Lower PTR	At 1%
Percentage of pupils with AEN	Lower PTR	At 1%	Lower PTR	At 1%	Lower PTR	At 1%
Lagged GCSE results	Lower PTR	Not quite sig	Lower PTR	At 1%	Lower PTR	At 1%
Revenue per pupil	Reduces PTR at a decreasing rate	At 1%	Reduces PTR at a decreasing rate	At 1%	Reduces PTR at a decreasing rate	At 1%
Adjusted r square	0.42		0.42		0.42	

Table 4 Summary of regression results for pupils per support staff (PPSS) 2000/1 to 20002/3

Explanatory variable	Direction of relationship	Statistical significance
Number of FTE pupils	Not significant	
Percentage of SEN pupils	Lowers PPSS at a decreasing rate	At 1%
Percentage of pupils eligible for FSM	Raises PPSS at a decreasing rate	At 1% not 2002/3
Capacity utilisation	Insignificant	
Sixth form	Raises PPSS	At 10%
Percentage of pupils with AEN	Not significant	
Lagged GCSE results	Raises PPSS	At 1%
Revenue per pupil	Lowers PPSS at a decreasing rate	At 1%
Adjusted R square	0.28 to 0.33	

Table 5 Summary of regression results for pupils per administrative and clerical staff (PPACS) 2000/1 to 2002/3

Explanatory variable	Direction of relationship	Statistical significance
Number of FTE pupils	Raises PPACS at a decreasing rate	At 1% or 5%
Percentage of SEN students	Not significant	
Percentage of pupils eligible for FSM	Raises PPACS at decreasing rate	At 1%
Capacity utilisation	Raises PPACS	At 1%
Sixth form	Reduces PPACS	At 10%
Percentage of pupils with AEN	Lowers PPACS	At 5% or 10%
Lagged GCSE results	Raise PPACS	At 1%
Revenue per pupil	Lowers PPACS at a decreasing rate	At 5% or 10%. Insignificant in 2001/2
Adjusted R square	0.15 – 0.18	

6. ORDINARY LEAST SQUARES ESTIMATES OF THE EFFECTS OF RESOURCES ON PUPIL ATTAINMENT AT KEY STAGE 3

In this section and in Section 7 we address the central research question: what is the impact of a marginal change in overall resourcing on pupil attainment at Key Stage 3? Our investigation of the relationship between resources and pupil attainment began with ordinary least squares (OLS) regression analysis, which is the standard technique for studying the extent of relationships between quantifiable variables.

Our OLS estimates control for clustering of pupils within schools as discussed in Section 2 on estimation issues. However, OLS does not allow for endogeneity and to address this key problem we also used instrumental variable (IV) techniques. Our IV results are described in Section 7.

6.1 Descriptive statistics

We begin with a descriptive summary of the data. After dropping cases with missing or unreliable data we were left with a sample of 464,783 pupils. Some descriptive statistics on this sample are shown in Table 6. The table is divided into four sections providing summary information on, respectively, the pupils themselves, the immediate neighbourhood in which they lived (from the Census), the schools which they attended and the LEAs in which the schools were located.

As would be expected the sample was quite evenly divided by gender, with fractionally more girls than boys. About 16 per cent of pupils were eligible for free school meals; about 16 per cent had SEN without having statements (school action/school action plus on the SEN code), while 2.6 per cent had SEN statements or were being assessed. We also had information on the ethnicity of the pupils in the sample. About 84 per cent was white, some 2.7 per cent black and nearly six per cent Asian. For Asian pupils we distinguished between Indian, Pakistani and Bangladeshi, and Asian-other since exploratory analysis found different coefficients for these sub-groups. Nearly five per cent of pupils had unclassified ethnicity, 2 per cent was mixed ethnicity, 0.3 per cent Chinese and 0.6 per cent was categorised as 'other' ethnic background. About 10 per cent of students was classified as having additional educational needs because of being in low achieving ethnic groups.[12] Over 7 per cent of pupils did not have English as their first language. Four local authorities, which are very small and/or could not be classified under political control, were omitted.

Table 6 Descriptive statistics

Pupil Level Variables

Variable	**Male**	**% No**	**Female**	**% Yes**	**Total**
Gender	231,168	49.7	233,615	50.3	464,783

Variable	**No**	**% No**	**Yes**	**% Yes**	**Total**
Eligible for free school meals	404,261	87.0	60,522	13.0	464,783
SEN school action/school action plus	414,288	89.1	50,495	10.9	464,783
SEN statement/process	459,483	98.9	5,300	1.1	464,783
English as first language	429,741	92.6	34,453	7.4	464,194

Ethnic Groups	**No**	**% No**	**Yes**	**% Yes**	**Total**
White	74,022	15.9	390761	84.1	464,783
Mixed	455,657	98.0	9126	2.0	464,783
Asian Indian	454,293	97.7	10,490	2.3	464,783
Asian Pakistani	454,891	97.9	9,892	2.1	464,783
Asian Bangladeshi	461,000	99.2	3,783	0.8	464,783
Asian Other	462,656	99.5	2,127	0.5	464,783
Black	452,032	97.3	12751	2.7	464,783
Chinese	463,225	99.7	1,558	0.3	464,783
Other	462,081	99.4	2,702	0.6	464,783
Unclassified	443,190	95.4	21,593	4.6	464,783

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Key Stage 3 Maths score (adjusted)	464783	6.032	1.222	0.143	8.963
Key Stage 3 Science score (adjusted)	464783	5.728	1.022	0.000	7.957
Key Stage 3 English score (adjusted)	464783	5.587	1.103	0.000	7.971
Key Stage 3 total score (adjusted)	464783	17.347	3.082	1.038	24.61
Key Stage 2 Maths score (adjusted)	464783	4.495	0.760	0.105	7.000
Key Stage 2 Science score (adjusted)	464783	4.760	0.585	0.105	6.778
Key Stage 2 English score (adjusted)	464783	4.515	0.672	0.000	6.889
Key Stage 2 total score (adjusted)	464783	13.770	1.824	1.466	19.47

*Adjustments to take account of level/tier

Census Variables

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Percentage unemployed in area	464782	0.034	0.026	0.000	0.280
Percentage with no qualifications in area	464782	0.305	0.128	0.000	0.853
Percentage with NVQ level 1 or below in area	464782	0.482	0.138	0.007	0.879
Percentage lone parent households	464730	0.209	0.143	0.000	1.000

School Level Variables

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
No of FTE Pupils (averaged)	3011	1007.87	334.24	51.67	2402.33
Capacity utilisation (averaged)	2994	0.98	0.15	0.33	2.50
Per cent eligible for free school meals (averaged)	3011	16.02	13.60	0.00	80.93
Per cent SEN with statements (averaged)	3011	2.59	1.81	0.00	22.40
Per cent SEN without statements (averaged)	3011	15.93	8.80	0.00	63.61
Per cent AEN (averaged)	3010	9.91	17.49	0.00	99.89
Staffing variables	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Pupil/teacher ratio (averaged)	3003	16.44	1.28	10.49	21.42
Pupil/Qualified teacher ratio (averaged)	3011	16.95	1.32	5.96	25.40
Support staff per pupil (averaged)	3011	93.39	40.78	11.57	783.38
Admin/clerical staff per pupil (averaged)	3011	157.75	45.85	30.01	503.11
Non-teaching staff per pupil (averaged)	3011	56.10	16.74	8.35	161.42

Financial variables	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Expenditure per pupil (averaged)	3011	2969.72	416.43	2053.60	10828.75
Secondary SSA per pupil (averaged)	147	3256.8	272.7	2864.49	4511.79
Teacher pay relative to average gross earnings in LA area (averaged)	147	1.103888	0.1508	0.81	1.41

*Variables are averaged over 2000/01 to 2002/03

Age Range	**No**	**% No**	**Yes**	**% Yes**	**Total**
Statutory Lowest Age 12	2,950	98.1	57	1.9	3,007
Statutory Lowest Age 13	2,892	96.2	115	3.8	3,007
Pupils aged 18/19 in school	1,451	48.2	1,560	51.8	3,011
School Type	**No**	**% No**	**Yes**	**% Yes**	**Total**
Comprehensive	335	11.2	2660	88.8	2,995
Secondary Modern	2,854	95.3	141	4.7	2,995
Grammar	2,836	94.7	159	5.3	2,995
Other	2,960	98.8	35	1.2	2,995
School Type - gender	**No**	**% No**	**Yes**	**% Yes**	**Total**
Boys school	2,831	94.0	180	6.0	3,011
Girls school	2,788	92.6	223	7.4	3,011
Mixed	403	13.4	2608	86.6	3,011
Religious Denomination of School	**No**	**% No**	**Yes**	**% Yes**	**Total**
Non-denominational	501	16.7	2,506	83.3	3,007
Church of England	2,865	95.3	142	4.7	3,007
Roman Catholic	2,673	88.9	334	11.1	3,007
Other Christian	2,989	99.4	18	0.6	3,007
Jewish	3,003	99.9	4	0.1	3,007
Muslim	3,005	99.9	2	0.1	3,007
Sikh	3,006	100.0	1	0.0	3,007
Policy Initiatives	**No**	**% No**	**Yes**	**% Yes**	**Total**
Specialist school	1,609	53.4	1,402	46.6	3,011
special measures	2,960	98.3	51	1.7	3,011
Education Action zone	2,804	93.1	207	6.9	3,011
Excellence in Cities	1,995	66.3	1,016	33.7	3,011
Beacon school	2,757	91.6	254	8.4	3,011
Leading Edge	2,918	96.9	93	3.1	3,011
Leadership Incentive Grant	1,660	55.1	1,351	44.9	3,011
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
School Competition Measures					
Number of schools in 1 km radius	3011	0.44902	0.701428	0	4
Number of schools in 2 km radius	3011	1.679508	1.753376	0	13
Number of schools in 5 km radius	3011	8.193955	7.864566	0	46
Number of schools in 10 km radius	3011	27.1717	28.57731	0	137

LEA Variables

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Teachers pay ratio (averaged)	149	1.11	0.15	0.81	1.42

Party in control of LEA	**1998**	**1999**	**2000**	**2001**	**2002**
Conservative	16	15	20	28	32
Labour	85	84	73	72	66
Liberal Democrats	9	11	11	8	7
No Over all Control	36	36	42	38	41
Total	146	146	146	146	146

The remaining pupil-level information reported is the scores on Maths, English and Science at Key Stage 2 and Key Stage 3. As discussed above, these are adjusted scores so that, for instance, a score of between six and seven at maths Key Stage 3 can be interpreted as the pupil attained level 6 on that test. The mean scores at Key Stage 3 are slightly higher for maths than for English or science. Scores vary from zero to almost nine for maths at Key Stage 3, and up to almost 8 for science and English. The distributions of the Key Stage 3 marks in each subject are shown in Figures 2 to 4. On viewing the distributions we were concerned about the 'spikes' which occur at certain values, and particularly about the possibility that these could have been introduced by our method of adjusting the raw scores to allow for tiers and levels. For example, in Key Stage 3 maths the spikes occur at scores of approximately 6 to 6.4 and 7 to 7.4. For science they also occur at these values; for English there also appears to be an excessive number of pupils scoring just over 5. Further investigations suggested that the spikes in the distribution had not been introduced by our data manipulation, rather they were present in the unadjusted data. The most likely explanation for this bunching at the lower end of each level is that where pupils are one or two marks off the next level an assessor is more likely to push them up to the next level by finding another couple of marks on their paper. Therefore pupils who should actually be at the top of the lower level tend to be pushed into the higher level.

Figure 2 Maths scores at Key Stage 3

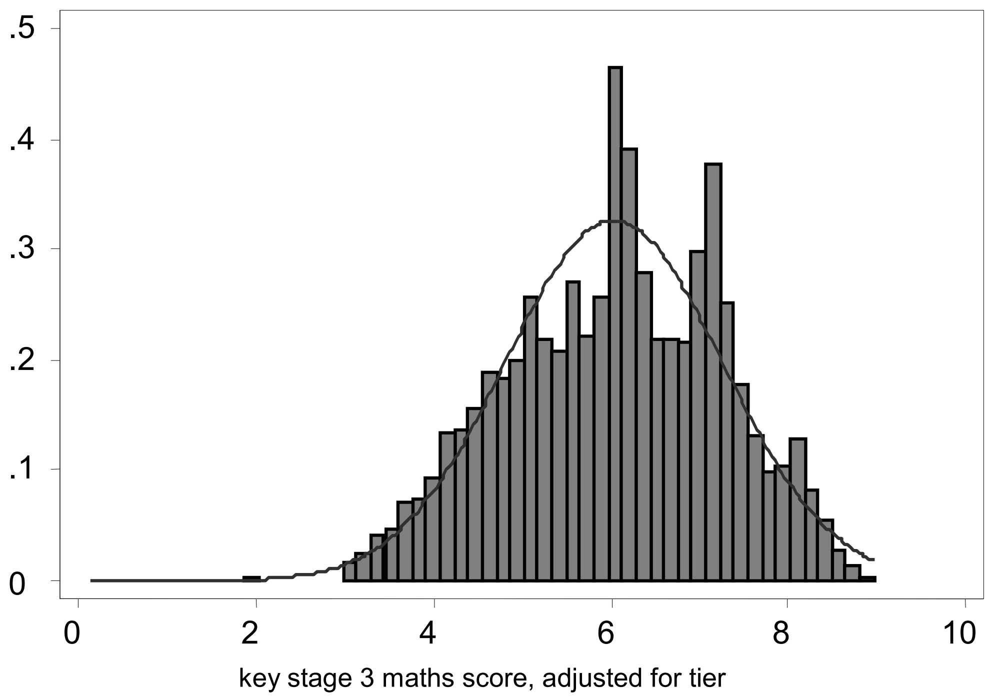


Figure 3 Science scores at Key Stage 3

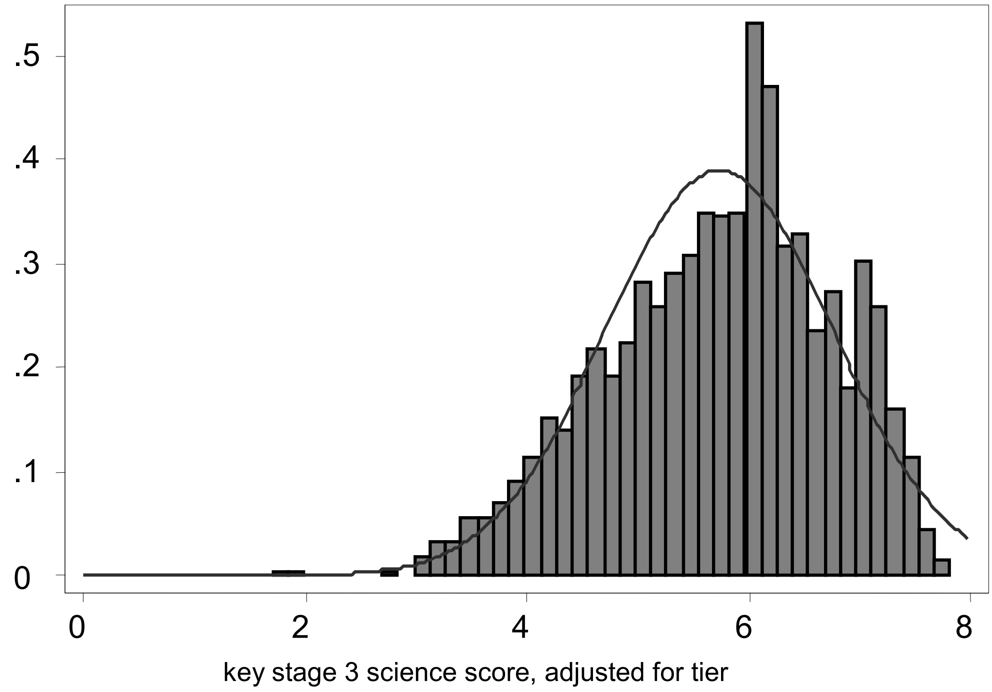
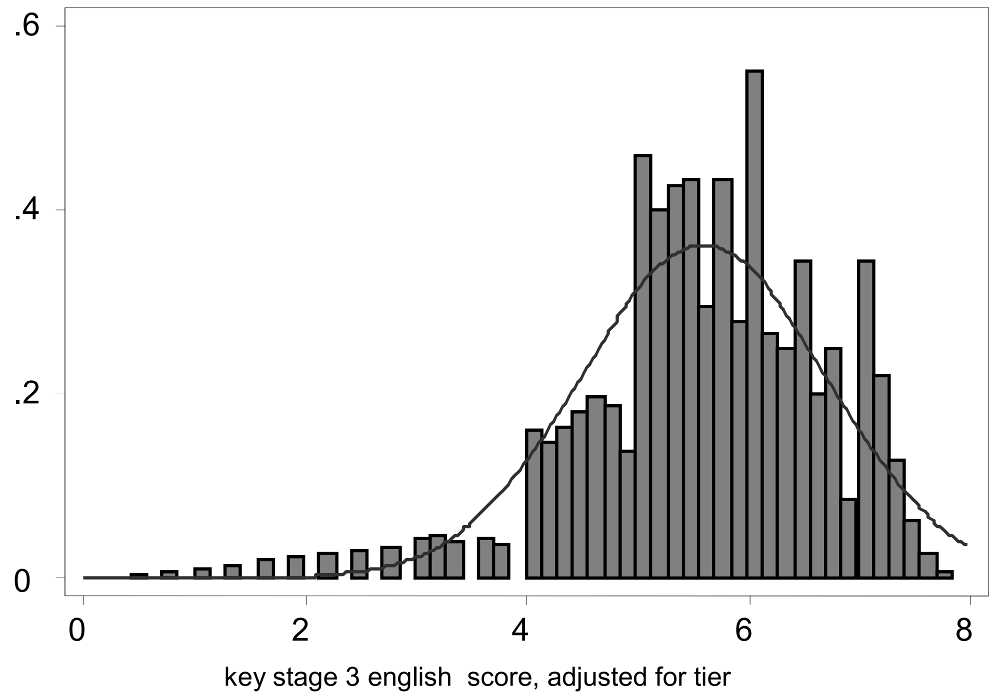


Figure 4 English scores at Key Stage 3



In order to take account of the socio-economic (SES) characteristics of different areas, Census variables measuring the proportion of households in an area with particular characteristics, such as ethnic composition, unemployment rates, proportion of single-parent families, and proportions without specified qualification levels, were utilised. The associative variables that were selected were chosen principally based on their ability to act as effective controls on the relationship of interest, i.e. the association between resourcing and KS3 educational outcomes. Therefore, it is important to note that the variables were not fully evaluated in terms of their ability to measure socio-economic status (this area of research is the subject of a current *Centre for the Economics of Education* research project). Equally, causality between the SES of an area and the educational attainment of a pupil living there is not implied in this analysis.

The variables chosen for the final model were selected because they explain some proportion of the variance in attainment when the other control variables in the model are included. Many of the other census variables also explain similar proportions of the variance in attainment, but are highly correlated with the ones included and are therefore omitted. The variables included relate to the 'output area' in which each pupil lived, the output area being a sub-ward level area definition available from the 2001 Census. The Census variables reveal that the mean unemployment rate in the areas in which the pupils lived was 3.4 per cent, with a range from zero to 28 per cent. The mean proportion of adults with level 1 or below qualifications was just under a half, and this varied from 7 to 88 per cent.

Our dataset has pupils nested in schools. There were 3,082 schools in total in our useable dataset, although some schools had missing data on some of the variables[18]. The actual regressions included 2,928 schools. The continuous variables were averaged over the period 2000/01 to 2002/03, as pupils were in these schools for three years prior to their Key Stage 3 tests. The average size of schools in the sample was just over 1,000 pupils, varying from the smallest schools with about 50 pupils to the largest with some 2,400 pupils.

The school level data contain several variables relating to staffing. The mean number of pupils per teacher was 16.4, there were 93 pupils per member of support staff, and 158 pupils per admin/clerical staff member on average in the sample of schools. The sample of schools was at 97.5 per cent of nominal capacity on average. Expenditure in the schools over the three years averaged £2,970 and revenue per pupil averaged £3,202.

A range of other information was available on the schools to include as controls in our regression analysis. Over 80 per cent of schools were non-denominational, most of the rest were Christian, with a very few Jewish, Muslim and Sikh schools in the sample. Some 57 schools had a statutory lowest age of 12 and 115 schools had a statutory lowest age of 13; more than half of the schools had a sixth form (measured by presence of pupils aged 18 or more). Most of the schools were comprehensive, but there were 141 secondary moderns, 159 grammar schools and 35 other types of school. Most of the schools were mixed, with 180 boys-only schools and 223 girls-only schools.

Government policy initiatives are likely to affect the resources available to schools and so were included in our analyses. Over 1,400 schools had obtained specialist status, while 51 schools were in special measures. Over 200 schools were located in Education Action Zones, and more than 1,000 participated in Excellence in Cities, 250 were Beacon schools. More than 1,600 schools benefited from Leadership Incentive Grants while about three per cent were in Leading Edge Partnerships.

We constructed measures of school competition based on the number of schools within a specified radius of each school in the sample. For the majority of schools there were no other schools within a 1km radius although some schools had up to four close competitors; on average there were roughly two schools within a 2km radius, and 8 within 5km. The number of schools within 10 km varied from zero in remote rural areas to more than 100 in some urban areas; the average was 27 schools.

At the LEA level, we constructed a ratio for teachers' pay relative to average earnings in the area. We interpret this variable as an indicator of teacher quality, on the standard assumption that the lower the relative earnings to a particular type of labour the less of it will be supplied and that those with the highest alternative earnings potential will not supply themselves to this local market. Relative teachers' pay was measured as the ratio of teacher pay at point M6 on the main salary scale to average gross labour market earnings (ONS local authority data) over the years 2000 to 2002. The M6 data used is the same across England, except for London where an inner London weighting applies to 19 LEAs and an outer London weighting applies to 14 LEAs. Local authority pay data are reported by county, metropolitan county or unitary authority. This means that one figure covers quite large areas of rural and urban mix in the north of England where there are metropolitan counties. Therefore, it is impossible to decipher very localised pay effects. The teachers' pay ratio had a mean value of 1.11, distributed between a minimum of 0.82 and a maximum of 1.42.

Data on the party in control of each LEA in each year between 1998 and 2002 are also listed in Table 6. Labour was consistently the strongest party during this period, although the number of LEAs under Labour control tended to decline over the period; the number of LEAs under Conservative control, and those with no party in over all control increased between 1998 and 2002.

6.2 OLS regression results

Ordinary least squares (OLS) regression models were run separately with the adjusted Key Stage 3 maths score, Key Stage 3 Science score and Key Stage 3 English score as the dependent variables. For each subject we began with a relatively sparse model containing only information about the pupil as explanatory variables. The prior attainment measure for the KS 3 maths and English regressions was the respective subject score at KS2; for KS3 science the prior attainment was the KS2 total score for all three subjects. The prior attainment measure with the highest correlation with the KS3 result was selected in each case. We then added in further controls for school level factors and finally variables obtained from Census data about the socio-economic characteristics of the local area in which the pupil lived. When school level variables were added, each regression included either a measure of school expenditure or measures of pupil/staffing ratios. School expenditure per pupil (adjusted for area cost differences) is interpreted as a measure of the real total resources applied per student. We estimate separate sets of equations, one with expenditure per pupil as the resource variable and another replacing expenditure per pupil by the two staffing variables – pupils per teacher and pupils per non-teaching staff. The expenditure and the staffing variables are not included in the same regression equation because they are highly correlated - teacher salary costs are on average 61 per cent of secondary schools' expenditure (OFSTED, 2003). As Todd and Wolpin (2003) point out, if expenditure per pupil is included as a regressor with the pupil teacher ratio, the coefficient on the latter will be biased downwards because for any given expenditure per pupil less is available for other inputs the lower the pupil teacher ratio.

These models, then, enable some answers to be given to the questions for each of the Key Stage 3 subjects: controlling for a range of other influences on pupil performance, what effects do small changes in school expenditure per pupil, in the pupil/teacher ratio and in the pupil/non-teaching staff ratio have on Key Stage 3 test scores? All our OLS models are robust to the presence of heteroscedasticity and the standard errors are adjusted to allow for the clustering of pupils within schools.[19] The estimates are presented in full in Appendix C and here we summarise the main findings.

Table 7 reports the coefficients on the expenditure variable in regressions for the Key Stage 3 test scores in maths, science and English. We report the models including the pupil and school controls and the models which also include the census variables. The two sets of estimates were, in fact, very similar.

Table 7 Summary of Key Stage 3 OLS regression results for expenditure

	Coefficient	**t-stat**
Models with pupil and school controls		
Key Stage 3 Maths	**0.0000295**	**2.39**
Key Stage 3 Science	**0.0000262**	**2.17**
Key Stage 3 English	-0.0000265	-1.15
Models with pupil, school and Census controls		
Key Stage 3 Maths	**0.0000267**	**2.20**
Key Stage 3 Science	**0.0000234**	**2.00**
Key Stage 3 English	-0.0000302	-1.32

Note: results in bold are statistically significant at 5% or less; full results are in Tables C2 and C4 in the Appendix.

It can be seen that, for Key Stage 3 maths and science, higher levels of expenditure per pupil were associated with higher test scores in these subjects. These positive associations between test scores and expenditure were statistically significant at the five per cent level. The magnitude of the coefficients are very small and suggest, roughly speaking, that a £100 increase in expenditure per pupil would be associated with a quarter of one per cent increase in test scores in maths and science, holding all other influences on these test scores constant.

For English at Key Stage 3 the expenditure coefficient is negative but not statistically significant so that it is not possible to reject the null hypothesis that there is no statistical association between English Key stage 3 test scores and expenditure per pupil once other factors have been controlled for.

In Table 8, the coefficients for the staffing variables in regressions for test scores at Key Stage 3 maths, science and English are displayed. Again we report models containing pupil and school variables, and also models with pupil, school and census variables. If resources have an effect on pupil performance, we would expect the signs on the pupil/staffing ratio coefficients to be negative so that, for example, a decrease in the pupil/teacher ratio is associated with higher scores at Key Stage 3. This is indeed the case for most of the variables in Table 8.

For the pupil/teacher ratio the signs on the coefficients for maths, science and English are all negative. However, only the coefficient for science is statistically significant. There is, then, strong evidence that lower pupil/teacher ratios are associated with higher Key Stage 3 test scores in science but for maths and English at Key Stage 3 we are unable to reject the null hypothesis of no statistical association between pupil/teacher ratios and test scores.

For the pupil/non-teaching staff ratio there is also no strong evidence of a statistical association between this variable and test scores in maths and science (neither is statistically significant at the five per cent level, although it is just significant for maths at the ten per cent level). The coefficients are negative for both of these variables as would be expected. However, for English there is a strong and statistically significant positive association between pupil/non-teaching staff and Key Stage 3 test scores so that more pupils per non-teaching staff member are associated with better test results in English. This is an unexpected and somewhat puzzling result and we explore further whether this result persists when using the more robust IV (instrumental variable) estimation procedures, which can take account of any potential endogeneity bias, in Section 7.

Table 8 Summary of Key Stage 3 OLS regression results for staffing

	Coefficient	**t-stat**
Models with pupil and school controls		
Key Stage 3 Maths:		
Pupil Teacher Ratio	-0.035152	-1.16
Pupil/Non-teaching staff Ratio	**-0.000384**	**-1.80**
Key Stage 3 Science:		
Pupil Teacher Ratio	**-0.009051**	**-3.08**
Pupil/Non-teaching staff Ratio	-0.000323	-1.60
Key Stage 3 English:		
Pupil Teacher Ratio	-0.004743	-0.86
Pupil/Non-teaching staff Ratio	**0.001119**	**2.83**
Models with pupil, school and Census controls		
Key Stage 3 Maths:		
Pupil Teacher Ratio	-0.002895	-0.98
Pupil/Non-teaching staff Ratio	**-0.000344**	**-1.66**
Key Stage 3 Science:		
Pupil Teacher Ratio	**-0.008500**	**-2.97**
Pupil/Non-teaching staff Ratio	-0.000289	-1.46
Key Stage 3 English:		
Pupil Teacher Ratio	-0.004284	-0.78
Pupil/Non-teaching staff Ratio	**0.001203**	**3.06**

Note: results in bold are statistically significant at 10% or less: full results in Tables C3 and C5 in the Appendix.

While the focus of this study is on the effect of resource variables on attainment, our model contains a range of other variables that are related to attainment, the findings for which are interesting to report. We do this after the section presenting the IV (instrumental variable) results for the resourcing variables. Here we note briefly the findings for the prior attainment at KS2, which all our estimates control for. Clearly, it would be anticipated that this variable would have a strong positive relationship with attainment at Key Stage 3 and this proved to be the case. We found that a non-linear relationship between prior attainment at KS2 and attainment at KS3 was an improvement on a simple linear relationship as the squared KS2 term is highly significant. For maths and English, terms in Key Stage 2 scores in these subjects worked best while for science it was the total score at Key Stage 2, which gave the best fit. The results predict not only that those with higher Key Stage 2 scores will obtain higher Key Stage 3 scores, but that this will occur at an increasing rate as Figures 5, 6 and 7 illustrate.

Figure 5: Estimated Effect of Prior Attainment on Key Stage 3 Maths Score

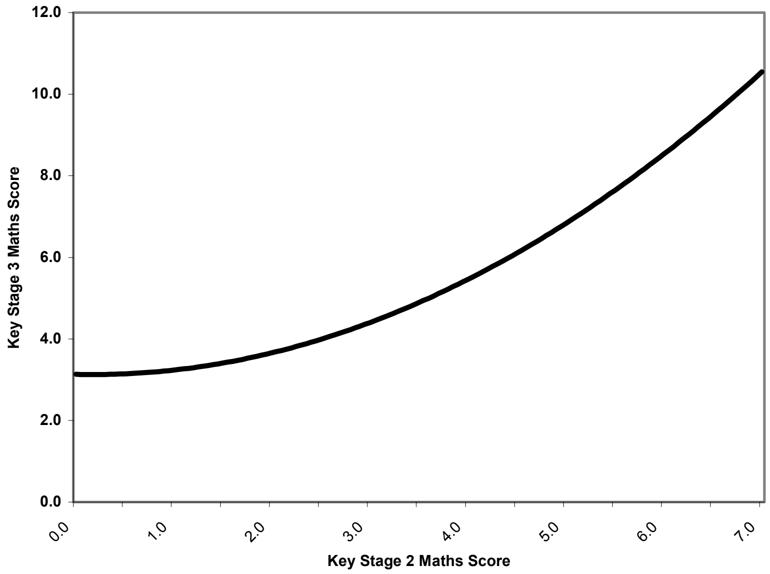


Figure 6: Estimated Effect of Prior Attainment on Key Stage 3 Science Score

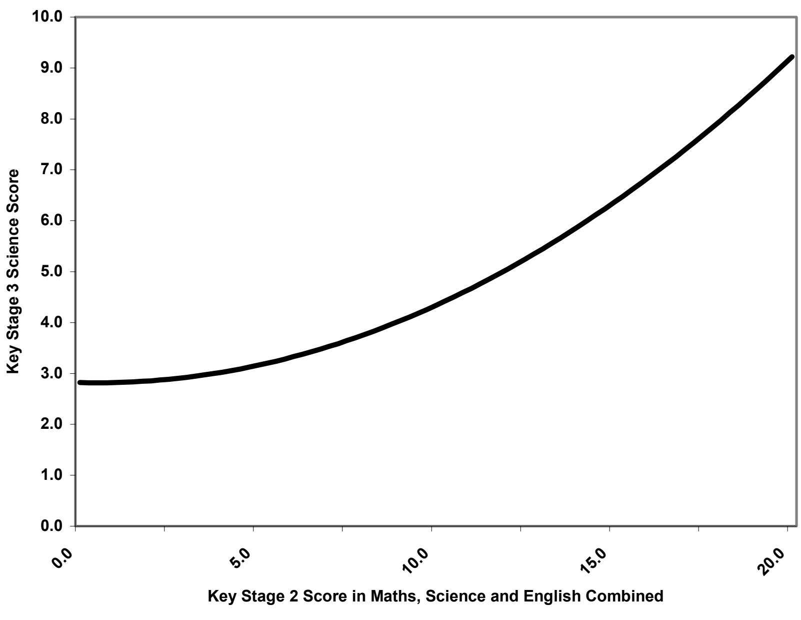
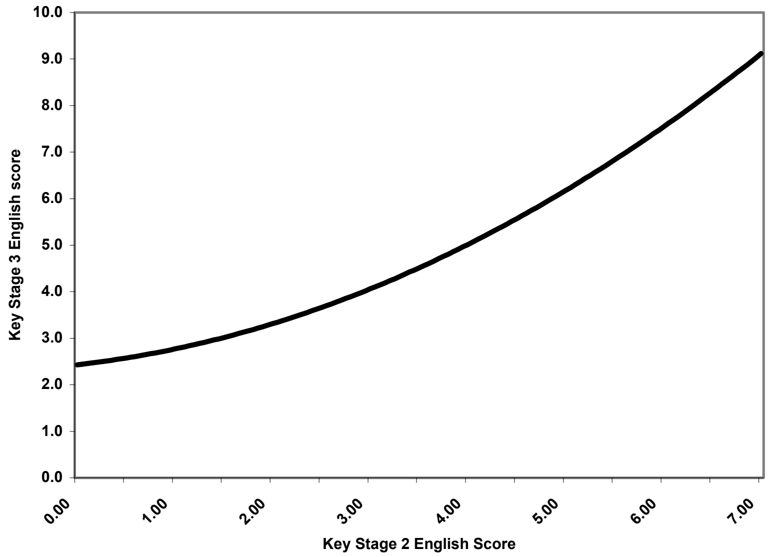


Figure 7: Estimated Effect of Prior Attainment on Key Stage 3 English Score



Overall, the OLS regression models worked reasonably well. The R-squared proportions for maths and science at Key Stage 3 were above 70 per cent, and the R-squared for English at Key Stage 3 was around 62 per cent, suggesting that the models were able to account for much of the variation in test scores at Key stage 3. The signs and magnitudes of the explanatory variables in the models were generally plausible. In terms of the main variables of interest, the resourcing variables, it was apparent that there were small but statistically significant associations between expenditure and Key Stage 3 scores in maths and science but not for English. For staffing, the pupil/teacher ratio was only statistically significant for science, while the pupil/non-teaching staff ratio was significant but incorrectly signed for English. However, the OLS regressions do not allow for the crucial problem of endogeneity and so the next stage of the analysis requires instrumental variable estimation.

7. INSTRUMENTAL VARIABLES ANALYSIS OF EFFECTS OF RESOURCES ON PUPIL ATTAINMENT

7.1. The methodological problem revisited

Although we have already discussed the problem of the endogeneity of school resources, it is useful to revisit the main arguments in favour of using an instrumental variables strategy. The main methodological difficulty in identifying the effect of school resources on pupil performance is the potential endogeneity of resourcing levels (Burtless, 1996; Mayston, 2002). Higher ability children, or children from wealthier backgrounds, may choose to go to better-resourced schools. If this occurs, school resources will be positively correlated with the wealth and social advantage of children's families. If wealth and social advantage impact on students' learning irrespective of school resources, then some of the apparent gain from additional school resources will in fact be caused by the beneficial effect of pupils' socio-economic background. In the UK, we have seen from the previous section that the endogeneity bias appears to work in the opposite direction. To compensate for socio-economic disadvantage, greater educational resources are allocated to poorer areas, disadvantaged schools and to weaker students. For example, resources are directed toward local education authorities on the basis of pupil numbers in various age bands, weighted by factors to reflect social need in the authority. Thus poorer LEAs receive higher levels of funding to compensate for the effects of being socio-economically disadvantaged. LEAs in turn allocate school budgets using formulae which include compensatory elements, in particular for pupils eligible for free school meals or with learning difficulties (Marsh, 2002). In this instance, we will observe in our data that schools with more socially disadvantaged and hence lower attaining pupils have higher levels of funding per pupil, thus hiding the true relationship between school inputs and pupil attainments (Burtless, 1996). The OLS models discussed in Section 6 above do not fully control for this potential problem and hence may generate biased estimates of the relationship between school resources and achievement.

From a technical viewpoint, endogeneity poses a problem because when it is present the error term in a standard OLS regression is likely to be correlated with the independent variables. If spending per pupil is increased and consequently raises attainment, this increase will feed back to resources, since these also depend on student attainment. Consequently the error term will not have zero covariance with the resource variables, thus violating an assumption required for OLS estimators to be consistent. We tested for this endogeneity and found evidence that it is a problem for both the expenditure per pupil and the pupil staff ratio variables. We therefore use an instrumental variable technique to overcome this problem, which we now discuss.

The IV method requires the researcher to find an instrument or variable that exerts no direct influence on pupil performance and only works indirectly through its role as a predictor of resources. In Section 5 we identified three sets of factors (i.e. instruments) that do influence the allocation of school resources among students but which we believe do not influence learning outcomes directly. The sets of variables are the Education Standard Spending Assessment (SSA)[20], indicators of the political control of the Local Authority in the relevant time period and the number of pupils on the school roll in the year prior to the students' entry to school. We are most confident that our political control variables and lagged school size do not have a direct influence on pupil performance and thus we generally only report results that use these instruments[21]. As has been said, a basic and testable requirement is that an instrument does adequately predict variation in the level of resourcing experienced by pupils. We explored this issue in depth and found that an F test of the joint significance of the instruments exceeded the 5% criteria in each case. Thus our potential instruments satisfy the very important requirement that they do predict expenditure per pupil and the pupil teacher ratio to an adequate extent.

7.2 Empirical results: main model

Table 9 summarises results from the main model used for this report, with both OLS and IV estimates presented side by side for comparison purposes. Two IV models are presented. The first utilises one instrument – political control – and the second two instruments – political control and school size. In the one instrument model the non-teaching staff variable is treated as exogenous. In the second IV model pupils per non-teaching staff can be treated as endogenous since we have two instrumental variables. The sample here is males and females combined and the results are presented separately for each KS3 subject. The controls used in the models are the full pupil, school and Census controls described in detail in Section 6, in relation to the main OLS results. We do not show the coefficients on all the controls, focusing only on the key resource variables, namely expenditure per pupil, the pupil teacher ratio and the number of pupils per non-teaching staff FTE (full time equivalent). The results in full are presented in Appendix D.

There are two main considerations when using an IV approach. Firstly, one must examine the extent to which the point estimates vary according to the methodology used. Thus it is clearly of interest to compare the magnitude of the OLS and IV estimates. The second consideration is the significance of the IV estimates. Although the IV method is extremely useful in overcoming the problem of endogenous explanatory variables, it does come at a cost. The standard errors of IV estimates are always larger than the OLS variance (if the OLS is valid) and generally the weaker the relationship between the instrument and the endogenous variables, the larger the standard errors (hence the requirement that the instrument and the endogenous variable be sufficiently correlated). With weak correlation between the instrument and the endogenous variable, the standard errors will be excessively large and we are likely to find that coefficients are insignificantly different from zero.

We undertook a number of statistical tests to ensure the validity of our instrumental variable approach. We found statistical evidence of endogeneity in the expenditure per pupil and the pupil-teacher and pupil-non-teaching staff ratio variables[22], justifying the use of IV. As has been said, our instruments are adequate in that they predict resourcing sufficiently to be used in the IV model. We found some evidence that one potential instrument, the SSA variable, did not pass the overidentifying restriction test in all cases. Thus we present results that focus on the political variable instruments and lagged school size[23].

Table 9 Summary of Key Stage 3 OLS and IV regression results for resource variables

	Ordinary Least Squares		**Instrumental variables (political control)**		**Instrumental variables (political control and school size)**	
Variable	**Coeff**	**t stat**	**Coeff**	**t stat**	**Coeff**	**t stat**
KS3 Mathematics						
Expenditure per pupil	**0.00003**	**2.20**	**0.00038**	**2.62**	**.000156**	**3.46**
Pupil teacher ratio	-0.00290	-0.98	**-0.09791**	**-2.48**	**-0.06701**	**-2.38**
Pupils per non teaching staff	**-0.00034**	**-1.66**	0.00021	0.64	-0.0009	-1.01
KS3 Science						
Expenditure per pupil	**0.00002**	**2.00**	**0.00036**	**2.61**	**0.00025**	**5.44**
Pupil teacher ratio	**-0.00850**	**-2.97**	**-0.12340**	**-2.87**	**-0.0913**	**-3.03**
Pupils per non teaching staff	-0.00029	-1.46	0.00039	1.09	**-0.0021**	**-2.38**
KS3 English						
Expenditure per pupil	-0.00003	-1.32	-0.00019	-0.71	-0.00012	-1.32
Pupil teacher ratio	-0.00428	-0.78	-0.0544	-0.80	0.073	1.34
Pupils per non teaching staff	**0.00120**	**3.06**	**0.0015**	**2.72**	**-0.0031**	**-1.86**

Note 1 All models pool males and females and control for the pupil, school and census variables described in detail in Sections 4 and 6. The instruments used for the first Instrumental Variable model are the set of variables describing the political control of the pupil's local authority. In this model pupils per non-teaching staff is assumed to be exogenous (hence it is not instrumented). In the second IV regression two instruments are used – political control and school size and pupils per non-teaching staff is treated as endogenous as well as the pupil teacher ratio.
Note 2 Results in bold are statistically significant at 10% or less. See Appendix D for full instrumental variables results.

In all cases, Table 9 suggests that the OLS estimate of the effect of expenditure per pupil is considerably smaller than the IV estimate, by a factor of up to 10 for expenditure. Thus the impact of expenditure per pupil on KS3 mathematics is 0.00003 and significant using OLS, whereas the effect is still significant but over ten times larger, 0.00038, using the IV approach with one instrument. The size of the effect is smaller when two instruments are used. A similar pattern can be observed for KS3 science. For English, a similar pattern occurs, although both the OLS and the IV estimates for expenditure per pupil are insignificantly different from zero.

It therefore appears that the true effect of expenditure per pupil on KS3 performance, in mathematics and science at least, is much larger than appears to be the case from the OLS results. This is consistent with a policy of compensatory resourcing, whereby the most able and socio-economically advantaged students attract fewer resources. Such students also get better results and therefore this produces a small, sometimes negative correlation, between educational expenditure and outcomes. Once we allow for this compensatory resource policy, via the use of instrumental variables, the estimate of the impact of expenditure on pupil performance becomes much larger, and in the case of Mathematics and Science rightly signed. Statistical tests suggest that our instruments are sufficiently correlated with expenditure per pupil, and this means that given our large sample sizes, we are obtaining relatively small standard errors even in our IV estimation. Hence the IV coefficients are not only larger but remain statistically significant.

Table 9 also summarises the effect of changes in the pupil teacher ratio on pupil outcomes. A similar pattern emerges. The coefficients on the pupil teacher ratio variables are substantially larger when the IV estimation method is used, but smaller in the two-instrument model than in the one instrument model. In the two-instrument model the coefficient on the pupil teacher ratio is 5 times higher for maths and 11 times higher for science than the OLS estimates. Again this reflects more resources being systematically allocated to schools with more socially disadvantaged pupils and those with greater learning difficulties. We find statistical evidence that one needs to account for this endogeneity in order to obtain reliable estimates of the impact of resourcing on pupil outcomes. For Mathematics and Science, our IV results suggest that increasing the pupil teacher ratio would indeed significantly reduce pupil performance. Specifically, an increase in the pupil teacher ratio of 1 would reduce pupil performance in Mathematics by between .1 and 0.07 of a level and by between .12 and 0.09 of a level in Science. As was the case for the expenditure per pupil variable, the results across Mathematics and Science are remarkably consistent. The story differs however when we consider English. The pupil teacher ratio does not have a significant effect on pupil performance in English, regardless of the methodology used.

Lastly, Table 9 presents the coefficients on the pupil per non-teaching staff FTE variable. The OLS estimates are negative but insignificant for maths and science. However, for English there is a significant positive effect from this variable. This is a counter-intuitive result suggesting that increasing the number of pupils per non-teaching staff FTE will increase pupil performance, though the magnitude of the effect is small. In the IV model which allows for the endogeneity of non-teaching staff, however, the coefficient on the non-teaching staff per pupil ratio took the correct, negative, sign for all three subjects. This implies that reductions in the pupil-non-teaching staff ratio are associated with higher KS3 scores. This effect was statistically significant for KS3 science, weakly significant for KS3 English (significant only at the ten per cent level) and insignificant for KS3 maths. The effect is much smaller for non-teaching staff than for teaching staff. Reducing the number of pupils per non-teaching staff by 10 would increase KS3 science by 0.02 of a level and English by 0.03 of a level.

The instrumental variables approach has been successful in identifying a stronger resource effect on maths and science attainment for both expenditure per pupil and the pupil teacher ratio. No correctly signed resource effects for expenditure and the pupil teacher ratio were found for English. Whereas the results for maths and science for all three resourcing variables are qualitatively the same for the OLS and two IV specifications this is not the case for English.

The absence of marginal resource effects with respect to expenditure and teachers for English, in contrast to maths and science, might be explained by stronger family background influence on English attainment, which relies more on the communication and reading habits of the family, whereas science and maths attainment are more dependent on direct teaching. While the evidence indicates that the pupil teacher ratio has an impact on attainment in both science and maths, increasing non-teaching staff per pupil was found to have a significant, positive impact on attainment only in science and English but not for maths. It is not immediately clear why there should be a significant effect in two subjects but not the other so we should probably be cautious in interpreting this result, especially as the results for non-teaching staff are so sensitive to the instruments used.

Although resource effects have been found they are small. Increasing expenditure by £100 per pupil (ceteris paribus) would raise maths and science attainment at KS3 on average by 0.04 of a level (in the one instrument model). Reducing the pupil teacher ratio for the whole school would raise maths attainment at KS3 by just under 0.07 of a level and science by 0.09 levels. However, other outcomes which are jointly produced with maths, science and English attainment, but for which we have no measures in our data set, might well also increase if revenue per pupil increased and the pupil-teacher ratio fell. It must also be borne in mind that we have imposed a linear form of the production relationship on the model. While the resulting estimates give guidance to the size of the effects from marginal changes, it would be unwise to extrapolate the relationship between resources and outcomes to large changes from current resourcing levels. So one cannot conclude that because we have found no resource effects for English that ceasing to employ English teachers would have no effect on pupils' attainment in English.

In this study we have presented the results in natural units for ease of understanding and interpretation. Using natural units enables us to report the effects of changes in resources in terms the effect of an extra pound of expenditure per pupil or a change in the pupil staff ratio by 1 pupil on levels of KS3 attainment. We have also converted the size of the effects in natural units into 'effect sizes' measured in terms of standard deviations, as this enables comparison of effect sizes across studies utilizing different natural units. These are presented in Table 10 for both IV models. So, for example, a 1 standard deviation increase in expenditure per pupil (which is £416.43) results in a 0.13 standard deviations of a level increase in KS3 maths attainment (for the model with one instrument) declining to 0.03 in the model with two instruments. The convention is that effect sizes below 0.2 are small. The effect size for science is between 0.15 and 0.1 for both expenditure per pupil and the pupil teacher ratio.

Table 10 Effect sizes of Key Stage 3 IV regression results for resource variables

	Instrumental variables (political control)	Instrumental variables (political control and school size)
Variable	**Coefficient**	**Coefficient**
KS3 Mathematics		
Expenditure per pupil	**0.13**	**0.05**
Pupil teacher ratio	**-0.10**	**-0.07**
Pupils per non teaching staff	0.003	**-0.01**
KS3 Science		
Expenditure per pupil	**0.15**	**0.10**
Pupil teacher ratio	**-0.15**	**-0.11**
Pupils per non teaching staff	0.006	**-0.03**
KS3 English		
Expenditure per pupil	-0.07 (not sig)	**-0.05**
Pupil teacher ratio	-0.06 (not sig)	0.08 (not sig)
Pupils per non teaching staff	**0.023**	**-0.05**

Note: the effect sizes show the impact of one standard deviation of the resource variable on KS3 results measured in standard deviations.

The main IV equations were also estimated for the Cobb-Douglas specification using a log linear form. The results, which are consistent with those using the linear form, and are summarised in Table 11 and given in full in Appendix E. These are the only results reported from the log-linear specification.

Table 11 Summary of Key Stage 3 IV regression results for resource variables using log linear specification (natural logs) (political instruments)

Variable	Coefficient	t stat
KS3 Mathematics		
Expenditure per pupil	**.21793**	**2.5**
Pupil teacher ratio	**-.3337**	**-2.44**
Pupil per non teaching staff FTE	**0.01215**	**2.35**
KS3 Science		
Expenditure per pupil	**.23751**	**2.63**
Pupil teacher ratio	**-.363256**	**-2.48**
Pupil per non teaching staff FTE	.009664	1.76
KS3 English		
Expenditure per pupil	-.06716	-.39
Pupil teacher ratio	-.09868	-.38
Pupil per non teaching staff FTE	**.020133**	**2.10**

Note: the full results are in Tables E1 and E2 in the Appendix

7.3 Empirical results: multilevel modelling

We also fitted the model to allow for variance at three levels – pupil, school and LEA. In the multilevel analysis, three-level models were fitted to allow for clustering of pupil KS3 attainment within schools and LEAs. While the standard errors from the OLS and IV models (Section 7.2) have been adjusted to take account of clustering within schools, LEA effects have not been considered. Although LEA effects are usually small relative to school effects, it is possible that the standard errors may still be underestimated, particularly for coefficients of LEA-level variables.

The multilevel model also differs from the OLS/IV models with robust standard errors in the way that it allows for clustering within schools. In a multilevel model, a random school effect explicitly allows for the presence of unobserved school-level variables that influence attainment of pupils within the same school, leading to clustering of pupil outcomes within schools. The multilevel models considered here also allow for unobserved LEA-level characteristics that could affect attainment of schools within the same LEA, leading to clustering of schools within LEAs.

In both the single-level IV model and multilevel model, we allow for the potential endogeneity of the school resource variables, expenditure per pupil and pupil/teacher ratio, by specifying two equations. In the first equation the dependent variable is pupil attainment, while in the second the dependent variable is one of the school resource variables. The two approaches differ in their specification of the residual component of the model. In the single-level model, each equation contains the usual pupil-level residual term. The endogeneity of school resources leads to a correlation between these residuals across the attainment and resource equations. In the multilevel model, the attainment equation contains three residuals or ‘random effects’ (corresponding to pupil, school and LEA) while the equation for school resources contains two residuals (corresponding to school and LEA). The school and LEA level residuals may both be correlated across equations, thus allowing for unobserved characteristics at either or both levels that might influence allocation of resources and pupil attainment. In summary, the multilevel approach recognises that the resource variables are defined at the school level and allows for selection effects that might operate at the school and/or the LEA level.

The equations in the single-level IV model may be estimated simultaneously, but a simpler and equivalent approach is to use two stage least squares (2SLS). In 2SLS the resource equation is estimated first, then the attainment equation is estimated with the resource variable replaced by predicted values obtained from the first stage (with an adjustment made to the standard error of the resource effect to allow for the fact that the values on the resource variable are now predictions rather than ‘true’ values). While it may be possible to extend this two-stage approach to estimate the multilevel IV model, the standard error adjustment would not be straightforward because of the more complex correlation structure between the two equations. In the multilevel case, it is actually more convenient to estimate the equations simultaneously. The IV model can be framed as a bivariate response model, which can be estimated in several software packages including MLwiN and SAS. The multilevel model was estimated with political control and school size as the two instrumental variables. There are two variants of the staffing model. In one only the pupil teacher ratio is assumed endogenous and in the other the pupil-non-teaching-staff ratio is also assumed endogenous. In the latter case three simultaneous equations are estimated together.

The effects of the resource variables on attainment estimated using the simultaneous equations multilevel model are shown in Table 12. The full results, together with the estimates obtained from a standard multilevel model which treats the resource variables as exogenous, are shown in Appendix F. All models were estimated using the MLwiN software.

The multilevel results are qualitatively remarkably similar to those from the IV models discussed earlier. In particular, they confirm our key result, which is that marginal increases in per pupil expenditure and reductions in the pupil teacher ratio have a significant but small positive impact on pupil attainment in maths and science but not English. When pupils per non-teaching staff is assumed endogenous, it is correctly signed and significant for all three subjects in the multilevel models, whereas it was insignificant for maths in the earlier IV models. The resource variables have the same signs for English attainment in both sets of regressions – expenditure per pupil and the pupil teacher ratio are incorrectly signed, being significant in the multilevel model and not in the earlier IV model with 2 instruments. The actual size of the coefficients is smaller in the multilevel models, particularly for the effect of expenditure per pupil and the pupil teacher ratio on maths attainment. The expenditure coefficients for science at 0.00025 and 0.00017 respectively are much closer. In both sets of models including pupils per non-teaching staff as an endogenous variable reduces the size of the coefficient on the pupil-teacher ratio for maths and science KS3 attainment, compared to a model in which non-teaching staff is assumed exogenous. Given the similarity in the results using the different methodologies we are content to focus only on the IV (2SLS) estimation method for the rest of the report, in order to evaluate the effect of marginal changes in resourcing levels on different sub-groups of the school population.

Table 12 Summary of Key Stage 3 IV regression results for resource variables using multilevel modelling (political and school size instruments)

Variable	**Coefficient**	**t stat**	**Coefficient**	**t stat**
KS3 Mathematics				
Expenditure per pupil	**0.00008**	**6.18**		
Non teaching staff assumed:	**exogenous**		**endogenous**	
Pupil teacher ratio	**-0.04445**	**-15.55**	**-0.01072**	**-3.76**
Pupil per non teaching staff FTE	0.00013	0.56	**-0.00148**	**-6.65**
KS3 Science				
Expenditure per pupil	**0.00017**	**14.36**		
Non teaching staff assumed:	**exogenous**		**endogenous**	
Pupil teacher ratio	**-0.09098**	**-32.95**	**-0.02170**	**-7.88**
Pupil per non teaching staff FTE	0.00013	0.61	**-0.00309**	**-14.33**
KS3 English				
Expenditure per pupil	**-0.00007**	**-3.264**		
Non teaching staff assumed:	**exogenous**		**endogenous**	
Pupil teacher ratio	0.00255	0.479	**0.05227**	**9.85**
Pupil per non teaching staff FTE	**0.00122**	**3.016**	**-0.00166**	**-4.10**

Note: full results are reported in Tables F1 to F3 in the Appendix.

8 OTHER FACTORS AFFECTING ATTAINMENT AT KS3

We report briefly our findings for other variables influencing test scores at Key Stage 3. The IV regressions for the linear model using the political instruments and including the staffing variables are summarised in Table 13 (full results are in Appendix D).

Other things being equal, girls did better than boys in the Key Stage 3 maths and English tests, while boys performed better than girls in science. Younger pupils are shown to catch up to a small extent[24]. Pupils with SEN and pupils eligible for free school meals were less likely to do well in the tests in all three subjects. Pupils eligible for free school meals performed 0.1 of a level worse after controlling for other factors. Pupils who did not have English as their mother tongue performed 10 per cent of a level better in English on average and 7 per cent and 5 per cent of a level better in maths and science. All the ethnic groups are compared to white pupils. Being Chinese added a quarter of a level in maths and slightly less in science and English. Indian Asians and other Asians also made slightly better progress than white pupils since KS2. Black pupils made just one percent of a level less progress in maths and science than whites but two percent of a level gain in English.

The results for the census variables show clear differences between having a particular ethnic origin as an individual (which generally was associated with more progress at KS3 than for white pupils) and living in an area with a high concentration of ethnic minorities. This is particularly noticeable for areas with higher proportions of Chinese and Pakistani/Bangladeshis, which had a negative association with KS3 attainment. Living in areas with higher unemployment and a poorly qualified population was also associated with lower KS3 attainment. For example if 50 per cent of the residents have level 1 or no qualifications, this reduces KS3 attainment on average by 0.2 of a level.

Among the school variables it was found that schools with statutory lowest ages of 12 (i.e. intake in Year 8) tended to achieve somewhat higher scores for maths. Schools with sixth forms did worse at KS3 maths and science. Boys-only schools tended to do better than mixed schools for maths and English and girls only schools for maths and science. Grammar schools had better results than comprehensives, while secondary moderns did worse at English. Denominational schools' KS3 results were not different from those of non-denominational schools except for English where Roman Catholic and Church of England schools did slightly better. Our study found fewer positive coefficients on KS3 attainment for denomination schools than did (Schagen et al., 2002) who, in their analysis, used fewer pupil level control variables for KS3 results in 2000. A range of policy measures affecting schools were included in the model. Pupils in specialist schools and Beacon schools tended to score more highly at Key Stage 3, while there was a negative effect of schools in special measures and schools with leadership incentive grants. It would be unwise to see these as necessarily causal effects however, especially as we only have one year of data. The last two indicators are probably indicative of schools in difficult circumstances.

Table 13 Instrumental Variables regressions for determinants of KS3 attainment (political instruments)

	KS3 maths		KS3 science		KS3 English	
	Coefficient.	sig	Coefficient.	sig	Coefficient.	sig
Pupil teacher ratio	-0.0979	***	-0.1234	***	-0.0544	
Pupil non-teaching staff ratio	0.0002		0.0004		0.0015	***
Girl	0.0549	***	-0.1179	***	0.1792	***
Age (days born after 31/8/89)	0.0002	***	0.0003	***	0.0000	***
SEN: school action/action plus	-0.3023	***	-0.1531	***	-0.3006	***
SEN: statemented	-0.3336	***	-0.0630	***	-0.3652	***
FSM eligible	-0.1034	***	-0.0936	***	-0.1134	***
Asian Indian	0.1131	***	0.0240	**	0.0681	***
Pakistani/Bangladeshi	0.0275	**	-0.0543	***	0.0409	**
Asian other	0.1684	***	0.1199	***	0.0901	***
Black	-0.0133	*	-0.0162	*	0.0172	*
Chinese	0.2417	***	0.1692	***	0.1318	***
Mixed ethnicity	0.0067		-0.0025		0.0162	*
English not first language	0.0679	***	0.0536	***	0.0971	***
KS2 maths/total/English	-0.0561	***	-0.0162	**	0.2357	***
KS subject score squared	0.1592	***	0.0168	***	0.1026	***
Sixth form	-0.0393	*	-0.0682	***	-0.0275	
Lowest age of pupils: 12	0.0688	***	-0.0403		0.0508	
Lowest age of pupils: 13	0.0518		-0.0426		-0.0361	
Boys' school	0.0448	**	-0.0125		0.1214	***
Girls' school	0.0756	***	0.1046	***	0.0271	
Grammar school	0.1769	***	0.1020	***	0.2128	***
Secondary modern school	0.0039		0.0249		-0.0532	*
Other type (not comprehensive)	0.0209		0.0221		0.0440	
Roman Catholic	0.0038		-0.0097		0.0333	*
Church of England	0.0154		0.0188		0.0608	**
Other Christian	-0.0478		-0.0616		-0.0204	
Jewish	-0.1867		-0.2293		0.1251	
Percentage pupils eligible for FSM	-0.0123	***	-0.0127	***	-0.0066	***
Percentage FSM pupils squared	0.0001	***	0.0001	***	0.0000	
Percentage AEN pupils	0.0007		0.0009	**	0.0008	
Specialist school	0.0063		0.0190	***	0.0279	**
School in special measures	-0.1138	***	-0.1162	***	-0.2215	***
Excellence in Cities or EAZ	0.0055		0.0015		0.0443	
Beacon school	0.0418	***	0.0429	***	0.0712	***
Leading Edge school	0.0090		-0.0191		-0.0012	
Leadership Incentive Grant school	-0.0548	***	-0.0634	***	-0.0418	
Teacher relative pay	0.1522	***	0.2825	***	0.2052	***
Urban area	-0.0196	**	-0.0363	***	-0.0152	
Capacity utilisation	0.1033	***	0.1153	***	0.0950	
Census output areas variables:						
proportion unemployed	-0.3522	***	-0.3872	***	-0.6385	***
proportion Black	-0.0825		-0.0685		-0.0809	
proportion Chinese	-0.4338	***	-0.4873	***	-0.0796	
proportion Bangladeshi or Pakistani	-0.1140	***	-0.2040	***	0.0523	
proportion Indian Asian	0.0181		-0.0761		-0.0236	
proportion lone parent households	-0.1971	***	-0.1887	***	-0.1278	***
proportion level 1 or 0 qualifications	-0.4066	***	-0.3402	***	-0.4042	***
Constant	4.7275	***	4.7975	***	3.1372	***

Note: ***significant at one per cent, ** five per cent *ten per cent

Peer group effects are captured by including the percentage of pupils in the school who are eligible for free school meals[25]. This had negative, non-linear effects on Key Stage 3 scores and we used quadratics to reflect this. For example on average, a pupil attending a school with 50 per cent of its pupils eligible for free school meals would achieve 0.55 of a level less in maths and science than if attending a school with only 5 per cent FSM pupils. Schools in urban areas had slightly lower KS3 scores in maths and science. The percentage of SEN pupils was found to have no significant effect, given the other controls, and so was not included in the final regressions reported. Capacity utilisation was associated with higher KS3 scores, but this variable is likely to reflect the popularity of a school with parents and therefore be related to its effectiveness.

As discussed earlier we also created a variable measuring teachers' pay relative to average gross earnings in the local authority area. As we do not have data on individual schools' or LEAs' pay rates for teachers we have used the top of the main salary scale plus inner or outer London weightings. We would expect that where relative teacher pay is higher, teacher quality is also higher as more effective teachers are more likely to apply for and therefore obtain jobs in these areas. This is the rationale for treating relative teacher pay as a proxy for teacher quality and hypothesising that the quality variable would be positive and significant in our regressions.

The relationship between teacher relative pay and attainment will be mediated by how schools respond to the difficulty of recruiting teachers. If schools' response is to recruit the same number of teachers per pupil, regardless of quality, then clearly teacher quality will be lower in areas where teachers are difficult to recruit due to low relative pay. In this case when we control for the PTR, relative teacher pay would pick up the effect of teacher quality. An alternative response when recruitment of good teachers is difficult is raising the pupil teacher ratio and either paying more to get good quality teachers, in which case there is less revenue per pupil to spend on other resources, or employing more support and administrative staff. In the case of these last two responses, for a given PTR, the lower relative pay of teachers reflects either fewer non-teaching resources or reduced marginal productivity from the additional non-teaching staff employed. Therefore when relative teacher pay is included as a regressor with the pupil teacher ratio and pupil non-teaching staff ratio we expect the former variable to proxy for teacher quality or for the effects of teacher recruitment problems on the other resources available to the school.

Teacher pay relative to average gross earnings was significant and positively signed for all three KS subjects in regressions of attainment which included the staffing variables. However, when the regression for attainment included revenue per pupil and not the staff variables, relative teacher pay was only positive and significant for English and science (in the model with 2 instrumental variables) and insignificant for maths. Relative teacher pay when included with revenue per pupil is difficult to interpret because it is highly negatively correlated with Area Cost Adjustment which we used to deflate revenue per pupil in order to take into account local differences in input prices. Also relative teacher pay tends to be lower in London, especially inner London where social deprivation is higher. It was necessary to include the area socio-economic indicators in the regressions to control for these factors for the coefficient on relative teacher pay to be positive and statistically significant.

The results for relative teacher pay as a proxy for quality are suggestive only. Better measures of teacher quality are required and as well more explicit modelling of schools' choices of inputs in response to the relative price of inputs and supply constraints before being able to draw more robust conclusions about the effects of teacher relative pay and teacher quality.

We are also interested in exploring whether competition among schools had any impact on the Key Stage 3 results. In principle, schools which were subject to stronger competitive pressures might have greater incentives to achieve good test results, as this would make the school more attractive to parents looking for a good school to which to send their child. Four variables were created to indicate the number of schools within a 1, 2, 5 and 10 km radius of each school. These were intended to act as rough measures of the extent of competition in the local schooling market. These are very similar to the measures of structural competition created by Bradley et al., (2001) who found them positively and significantly related to measures of school efficiency derived from data envelopment analysis. We tested each of the variables separately in the resourcing regressions. The coefficients on the 1km and 5km variables were invariably non-significant, while the 2km variable tended to be borderline significant; the 10km variable in fact appeared to be the most promising but was also not consistently positive and/or significant. Given that these results were inconsistent and difficult to interpret, in the final model it was decided not to include any of the variables because we could not be certain that they were truly measuring the extent of competition rather than, say, population density or other characteristics of the local area. This is clearly, however, an important topic on which more research is needed.

9 DO RESOURCES HAVE DIFFERENTIAL EFFECTS ON DIFFERENT GROUPS OF PUPILS AND SCHOOLS?

It is important to investigate whether the impact of additional resources varies systematically across different groups of pupils. Do resource effects vary by gender, by ethnic group, by prior attainment, by eligibility for free school meals, or by SEN status? To address these issues separate regressions were run for each of these sub-groups. The instrumental variable specification (with the political control variable) as discussed in Section 7 was used throughout. A summary of the results will be presented here and some of the estimates are shown in more detail in Appendix G.

9.1 Gender

Table 14 summarises the expenditure and staffing regressions run for boys and girls separately.

Table 14 Expenditure and pupil teacher ratio regressions for boys and for girls

KS3 Maths	**Males**		**Females**	
	Coefficient	**t-stat**	**Coefficient**	**t-stat**
Expenditure per pupil	0.0003836	2.45	0.0003745	2.40
Pupil teacher ratio	-0.1015	-2.51	-0.0951	-2.04
KS3 Science	**Males**		**Females**	
	Coefficient	**t-stat**	**Coefficient**	**t-stat**
Expenditure per pupil	0.0003109	2.15	0.0004261	2.68
Pupil teacher ratio	-0.1186	-2.75	-0.1307	-2.60
KS3 English	**Males**		**Females**	
	Coefficient	**t-stat**	**Coefficient**	**t-stat**
Expenditure per pupil	-0.0000144	-0.05	-0.0003482	-1.26
Pupil teacher ratio	-0.01259	-0.18	-0.1011	-1.27

The results suggest that the extent of the association between resourcing and pupil outcomes at Key Stage 3 was remarkably similar for boys and for girls. The coefficient estimates and statistical significance levels show little difference. Statistically significant resource effects were identified in maths and science but not in English. There is no evidence of differential resource effects by gender.

9.2 Ethnicity

The dataset contains information on the ethnicity of the pupil enabling an analysis to be undertaken of whether the effects of resourcing differ by ethnic group. Little evidence was found that either expenditure or staffing variables had differential effects for the various ethnic groups. Table 15 summarises the results for expenditure. In maths and in science, the expenditure coefficient was statistically significant only for white pupils but this is most likely a consequence of the fact that white pupils constitute by far the largest ethnic group. The smaller samples for the other ethnic groups mean that standard errors are larger and statistically significant effects less likely to be observed. There were no significant results for any ethnic group for English at Key Stage 3.

TABLE 15: Summary of regression results for expenditure by ethnic group

Maths KS3	**Coefficient**	**t-stat**
White	0.0003526	2.57
Black	-0.0002079	-0.88
Asian, Indian	0.0000367	0.19
Asian, Pakistani/Bangladeshi	0.0006337	1.30
Asian Other	0.0023612	0.54
Chinese	0.0009399	1.44
Mixed	-0.0003035	-0.56
Science KS3	**Coefficient**	**t-stat**
White	0.0003274	2.47
Black	-0.000396	-1.63
Asian, Indian	0.0001594	0.93
Asian, Pakistani/Bangladeshi	0.0010171	1.64
Asian Other	0.0006636	0.26
Chinese	0.0004453	0.75
Mixed	-0.0002092	-0.39
English KS3	**Coefficient**	**t-stat**
White	-0.0001694	-0.67
Black	-0.0006008	-1.46
Asian, Indian	-0.000588	-1.93
Asian, Pakistani/Bangladeshi	0.0003594	0.57
Asian Other	-0.0008233	-0.27
Chinese	-0.0003334	-0.46
Mixed	-0.0001925	-1.34

Table 16 reveals a very similar pattern of results for the pupil/teacher ratio – statistically significant effects for white pupils in maths and science at KS3, but little or no evidence of differential effects by ethnicity.

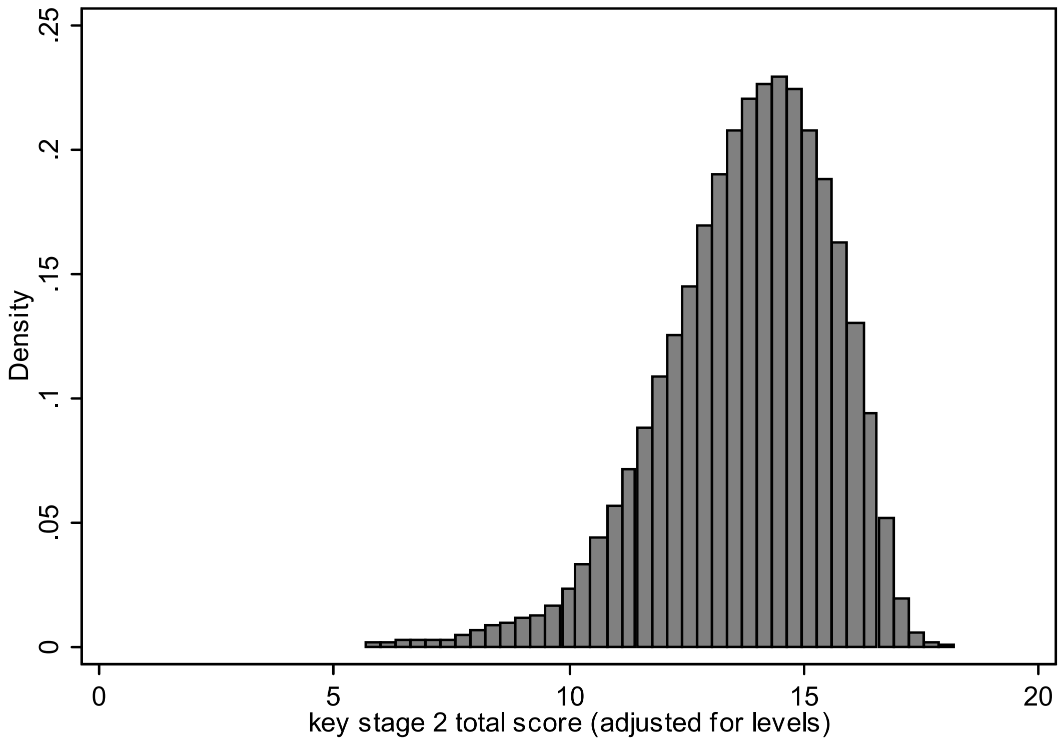
TABLE 16 Summary of regression results for pupil teacher ratio by ethnic group

Maths KS3	**Coefficient**	**t-stat**
White	-0.0858238	-2.33
Black	-0.2107181	-0.61
Asian, Indian	-0.0342716	-0.73
Asian, Pakistani/Bangladeshi	0.0956144	1.53
Asian Other	0.1763278	1.31
Chinese	-0.1796969	-1.51
Mixed	0.0132291	0.17
Science KS3	**Coefficient**	**t-stat**
White	-0.1058571	-2.71
Black	-0.409624	-0.70
Asian, Indian	-0.0750761	-1.72
Asian, Pakistani/Bangladeshi	-0.0181633	-0.32
Asian Other	0.1627518	1.37
Chinese	-0.1491114	-1.38
Mixed	-0.0247671	-0.33
English KS3	**Coefficient**	**t-stat**
White	-0.0274924	-0.43
Black	-0.7263988	-0.76
Asian, Indian	0.0820192	0.93
Asian, Pakistani/Bangladeshi	0.2423843	1.88
Asian Other	-0.0864656	-0.60
Chinese	-0.1254206	-0.94
Mixed	-0.0690163	-0.57

9.3 Prior Attainment

The combined score in maths, science and English at Key Stage 2 was used as the measure of prior attainment. Its distribution is shown in Figure 8.

Figure 8: Total score (maths, science and English) at Key Stage 2



The total score at Key Stage 2 was broken down by quintile and separate regressions were run for each quintile. The coefficients on expenditure for regressions of attainment at Key Stage 3 by quintiles of prior attainment are shown in Table 16, and the pupil teacher ratio coefficients are shown in Table 17. For maths at Key Stage 3 there is evidence of a statistically significant association with expenditure for each of the first four quintiles while for the lowest quintile we cannot quite reject the null hypothesis of no statistical association at the 95% level. For science and expenditure the coefficients differ significantly from zero for all five quintiles.

To test whether the coefficients on expenditure for the different quintiles are significantly different from each other, two sample t-tests were run. For maths and science expenditure the null hypothesis of no difference between quintile 1 and 2 (and hence the rest) cannot be rejected at 95% confidence.

Again from looking at the magnitude of the coefficients there is at least weak evidence that the association between expenditure and pupil outcomes in KS3 science are least for the highest quintiles of prior attainment.[26] There is no evidence of statistical associations between expenditure and English test scores at KS3 for any of the quintiles of prior attainment at KS2.

Table 17 Expenditure regression coefficients by KS2 attainment quintiles

Quintile	**Coefficient**	**t-stat**
Maths KS3		
1st Quintile	0.0003454	2.44
2nd Quintile	0.0005697	3.07
3rd Quintile	0.0005877	2.81
4th Quintile	0.0005632	2.48
5th Quintile	0.0004131	1.91
Science KS3		
Quintile	Coefficient	t-stat
1st Quintile	0.0002858	2.35
2nd Quintile	0.0005226	2.99
3rd Quintile	0.0003879	2.15
4th Quintile	0.000519	2.40
5th Quintile	0.0004841	2.05
English KS3		
Quintile	Coefficient	t-stat
1st Quintile	-0.0001172	-0.54
2nd Quintile	-0.0000316	-0.12
3rd Quintile	-0.0001077	-0.36
4th Quintile	-0.0001043	-0.30
5th Quintile	-0.0002289	-0.47

As for the staffing regressions (Table 18) for maths the pupil/teacher ratio was significantly different from zero for the highest three quintiles of prior attainment, while for the bottom two quintiles it was not significantly different from zero (at the five per cent significance level). In science a similar pattern was evident with the pupil/teacher ratio most strongly associated with pupil outcomes for the highest three quintiles, while the evidence of effects of the pupil/teacher ratio was noticeably weaker for the fourth and especially the fifth quintiles of prior attainment. The t tests do not reject the null hypothesis of no difference between staffing coefficients for quintiles 1 and 2 in maths at 90% confidence. (The null hypothesis would not be rejected at 85% confidence for the science PTR coefficient). In English there was very little evidence of relationships between the pupil/teacher ratio and KS3 outcomes for any of the quintiles of KS2 attainment.

Table 18 Staffing regression coefficients by KS2 attainment quintiles

Maths KS3	**Coefficient**	**t-stat**
1st Quintile	-0.0674743	-1.97
2nd Quintile	-0.1600052	-2.93
3rd Quintile	-0.1234172	-2.43
4th Quintile	-0.1176922	-1.82
5th Quintile	-0.0967032	-1.73
Science KS3	**Coefficient**	**t-stat**
1st Quintile	-0.1017349	-2.96
2nd Quintile	-0.1729637	-3.07
3rd Quintile	-0.1414035	-2.71
4th Quintile	-0.129674	-2.00
5th Quintile	-0.092417	-1.56
English KS3	**Coefficient**	**t-stat**
1st Quintile	-0.0572709	-1.14
2nd Quintile	-0.1354337	-1.84
3rd Quintile	-0.0888834	-1.19
4th Quintile	-0.0213437	-0.22
5th Quintile	-0.0066312	-0.05

9.4. Free School Meals

There is some evidence of a stronger relationship between the resourcing variables and pupil test scores at Key Stage 3 for those who were eligible for free school meals (FSM), compared to pupils who were not eligible for free school meals. Table 19 summarises the relationship between expenditure and KS3 attainment for each of these groups as well as that between the pupil teacher ratio and attainment. The coefficients for maths and science are noticeably larger for FSM pupils than for non-FSM pupils. The differences between the coefficients for expenditure per pupil for the two groups were significantly different from zero at 95% confidence for science and maths. There were no statistically significant effects for either group in Key Stage 3 English or for the pupil teacher ratio for all three subjects.

Table 19 Expenditure and pupil teacher ratio regression coefficients according to pupil's eligibility for free school meals

KS3 maths				
	Pupil eligible for FSM		*Not eligible for FSM*	
Coefficient	Estimate	t-stat	Estimate	t-stat
Expenditure per pupil †	.0009875	2.35	.0003109	2.34
Pupil teacher ratio	-.1406195	-1.41	-.096522	-2.53
KS3 science				
	Pupil eligible for FSM		*Not eligible for FSM*	
Coefficient	Estimate	t-stat	Estimate	t-stat
Expenditure per pupil †	.00113	2.41	.0002892	2.26
Pupil teacher ratio	-.1967552	-1.75	-.1178018	-2.86
KS3 English				
	Pupil eligible for FSM		*Not eligible for FSM*	
Coefficient	Estimate	t-stat	Estimate	t-stat
Expenditure per pupil	.0007588	1.25	-.0002537	-1.02
Pupil teacher ratio	-.1970346	-1.09	-.0454588	-0.71

Note 1: † these point estimates are significantly different at 90% confidence.
Note 2: full results are reported in Tables G1 and G2 for maths and science.

The top quintile by KS2 attainment was grouped by those eligible for free school meals (4,499 pupils) and those not eligible (82,874). The summary estimates are given in Table 20. The coefficient on expenditure per pupil for those eligible for FSM was twice as high for maths and 3.7 times larger for science than that for non-eligible pupils and the latter were significantly different at 90% confidence. The effect of the PTR was also twice as high for science for the FSM pupils. The most surprising result is that despite the small number of pupils, the coefficients for English for both revenue per pupil and PTR were correctly signed and significant (at 10% for the PTR) which was not the case for any other pupil group.

Table 20 Expenditure and pupil teacher ratio regression coefficients for pupils in top KS2 attainment quintile by whether pupil eligible for free school meals

Top quintile by KS2 attainment				
KS3 maths	*Pupil eligible for FSM*		*Not eligible for FSM*	
Coefficient	Estimate	t-stat	Estimate	t-stat
Expenditure per pupil	.000842	1.76	.0003311	2.38
Pupil teacher ratio	-.1117461	-1.02	-.0657712	-1.94
KS3 science	*Pupil eligible for FSM*		*Not eligible for FSM*	
Coefficient	Estimate	t-stat	Estimate	t-stat
Expenditure per pupil †	.001015	2.13	.0002738	2.31
Pupil teacher ratio	-.220404	-1.88	-.0994727	-2.93
KS3 English	*Pupil eligible for FSM*		*Not eligible for FSM*	
Coefficient	Estimate	t-stat	Estimate	t-stat
Expenditure per pupil	.001218	2.03	-.000155	-0.72
Pupil teacher ratio	-0.256415	-1.75	-.04665	-0.93

† These point estimates are significantly different at 90% confidence.

9.5. Special Educational Needs (SEN)

Analyses were run separately and then compared for three different categories of pupil here: those without special educational needs; pupils who were eligible for school action/school action plus, and pupils who had statements of SEN/were being assessed for SEN. Table 21 summarises the results of regression analyses for each of these sub-groups and reports the estimated coefficients for both the expenditure and staffing variables.

Associations between Key Stage 3 test scores and expenditure in maths and in science were evident for non-SEN pupils and for school action/ action plus pupils, but appeared much weaker for pupils with SEN statements/assessed for SEN. Significant relationships between the pupil/teacher ratio and KS3 test scores in maths and science were found only for pupils with no SEN. It should be borne in mind that the data with respect to SEN may be deficient. The identification and classification of SEN is dependent on school and LEA policies and practice. Also the resourcing of SEN within schools may not be well reflected in school level resource variables since the ways in which SEN pupils receive additional support are dependent on internal resource allocation practices. A further consideration is that SEN pupils often take other awards and qualifications than KS3 tests and we have no data on these.

Table 21 Summary of regression results for expenditure and for pupil teacher ratio by SEN status

KS3 maths	*Pupils with no SEN*		*Pupils on school action & action plus*		*Pupils with statements of SEN or being assessed*	
Coefficient	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
Expenditure per pupil	.0004074	2.81	.0003912	1.55	-.000506	-0.80
Pupil teacher ratio	-.1115588	-2.70	-.0369645	-0.72	.2473506	0.70
KS3 science	*Pupils with no SEN*		*Pupils on school action & action plus*		*Pupils with statements of SEN or being assessed*	
Coefficient	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
Expenditure per pupil	.0003685	2.69	.0005047	1.80	.0000248	0.04
Pupil teacher ratio	-.1356012	-3.05	-.020775	-0.38	-.0574219	-0.18
KS3 English	*Pupils with no SEN*		*Pupils on school action & action plus*		*Pupils with statements of SEN or being assessed*	
Coefficient	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
Expenditure per pupil	-.0001572	-0.63	-.0001445	-0.27	-.0006434	-0.64
Pupils per non teaching staff	.0016095	3.11	-.0002501	-0.18	.0036938	0.64

10 POLICY IMPLICATIONS

This is the first research, as far as we are aware, to estimate a school production function using contemporaneous pupil level data for English secondary schools from PLASC. Using these data we have been able to utilise additional variables for controlling for pupil background not previously available nationally and also to attempt to correct for endogeneity by making use of exogenous variation in school funding. The policy implications are necessarily tentative until the main findings of this study are confirmed or otherwise by replication for different years and different Key Stage attainment measures.

The main finding is that there are positive resource effects for pupil attainment in KS3 maths and science. This finding is robust to the methodology used in the estimation. Even our IV models do not suggest a significant and correctly signed effect of expenditure per pupil and the pupil teacher ratio on attainment in English. Secondly, the magnitude of the effect from expenditure per pupil is much larger when we use IV estimation than OLS, providing evidence of compensatory resourcing. In other words, as additional resources are allocated to poorer performing children, some of the positive relationship between resourcing and outcomes is hidden in OLS studies that simply relate per pupil funding to pupil outcomes. Studies are likely to produce biased estimates if they do not attempt to overcome the endogeneity in the resource variables. Our findings do not, however, mean that we have found a large resource effect. In fact our results suggest that a £100 increase in per pupil expenditure in secondary schools would only lead to a 0.03 increase in the level of pupils' mathematics and science KS3 attainment. This is a small effect for a substantial increase in expenditure.

The effect is slightly larger if the pupil teacher ratio is reduced rather than having an overall increase in spending, as shown in Table 22 using the results from the IV model with one instrument. The cost of reducing the pupil teacher ratio by 1 pupil is assumed to be the increased cost per pupil of having 15.44 pupils per teacher on average compared to 16.44, which was the mean PTR over the years 2000/1 to 2002/3. The cost of reducing the PTR by 1 is therefore approximately £127.17 per pupil: it is derived from costing a teacher at the top of the main professional grade in 2003/4 and adding 22% on costs (£32,281). Comparing a general increase in expenditure of £100 per pupil with that of spending the same amount of money reducing the pupil teacher ratio suggests that the latter would have more effect on attainment: 0.07 of a level compared with 0.04 for maths and 0.09 of a level compared to 0.04 for science. It is also worth noting that the estimated effects on pupil outcomes are smaller than they might be if we had measures of the other pupil outcomes that are produced jointly with maths and science.

Table 22 Indicative effects on KS3 maths and science attainment of increased spending

	All pupils		Pupils eligible for FSM	
	Increase in KS3 maths level	Increase in KS3 science level	Increase in KS3 maths level	Increase in KS3 science level
Coefficient on expenditure per pupil (t statistic)	0.00038 (2.62)	0.00036 (2.61)	0.00099 (2.35)	0.00113 (2.41)
Increase in expenditure per pupil of £100	0.038	0.036	0.099	0.113
Coefficient on pupil teacher ratio (t statistic)	-0.09791 (-2.48)	-0.1234 (-2.87)	-0.14062 (-1.41)	-0.19676 (-1.75)
Reduction in PTR by 1 costing £127.17 per pupil in 2003/4	0.0979	0.1234	0.1406	0.1968
Reduction in PTR of 0.79 costing £100 per pupil	0.0708	0.0944	0.1106	0.1547

Note: these effects are based on IV regressions with political control as the only instrumental variable. The estimated effects would be smaller if coefficients from IV models and multilevel with two instruments were used.

The estimated positive effects on attainment of reducing the ratio of pupils to non-teaching staff are less robust than those for expenditure per pupil and the pupil teacher ratio and are also smaller. For science this was statistically significant at 95% and at 90% for English. For maths this variable took the correct sign in our IV regression models but was not statistically significant. In the multilevel estimations the non-teaching staff resource variable was correctly signed and significant at 95% for all three subjects. The effect of reducing the number of pupils per non-teaching staff by 10 varies between .015 and .03 of a KS3 level depending on estimating model and subject. The effect is much smaller than for the pupil teacher ratio. Reducing this by 10 pupils raises maths and science attainment between 1.2 and 0.2 KS3 levels. Even taking account of the lower salary costs of non-teaching staff, the impact of increased expenditure on staff is considerably greater for teachers than non-teaching staff. The findings for non-teaching staff should be interpreted with particular care since they are sensitive to the instruments used.

There is some tentative evidence that teacher quality as reflected in relative teacher pay rates has a small effect on attainment. Given our rather crude measure of teacher quality based on the assumption that it varies with relative pay, this finding is suggestive at best.

In the main we found little differential effect on resourcing for different kinds of pupils, apart from the impact of additional resources on pupils eligible for free school meals. The effect of expenditure per pupil on students eligible for free school meals was about three times as much as that for pupils not eligible for FSM for maths and about four times greater for science. The impact of reducing the PTR was 1.6 times greater for maths attainment and about 1.5 time larger for science (though the latter did not reach significance at 10%). There is some weaker evidence of a greater effect of resourcing on pupils in the middle two quintiles than for those in the highest and lowest quintiles. The most striking finding is the greater resource effects for pupils in the top quintile by KS2 attainment and eligible for free school meals compared to those in the top quintile but not eligible. The able but poor students were the only ones for whom additional expenditure and a lower PTR had a positive and significant effect on English attainment.

11 Summary of Results and Conclusions

Statistically robust studies of the education production function require data on pupil progress from one level of attainment to another, on other pupil characteristics, on the level of school resources per pupil during the period over which pupils' progress is measured, and information on school type and context. If the data are from a natural setting, rather than from an experimental setting, the estimation method should also correct for the potential endogeneity of resources. In England, the main source of such endogeneity is compensatory funding of schools with higher concentrations of socially disadvantaged pupils and pupils with greater learning needs. This study used the national administrative data set for English schools (PLASC), combined with additional data on the determinants of local authorities' school funding, to undertake a large scale and statistically robust estimation of the effects of resources on pupils' attainment. With data on roughly 3000 English secondary schools and over 430,000 pupils for the years 2000/1 to 2002/3, it is one of the first examples of the type of high quality analyses that can be done in this field using this new dataset.

We have estimated a model in which Key Stage 3 maths, science and English attainment are dependent on prior attainment at KS2, the pupils' age, gender, SEN category, ethnicity, having English as a first language and being eligible or not for free school meals. In addition, we control for the socio-economic characteristics of the neighbourhood the pupil lives in. At school level the variables controlled for include size, social composition of the student body, age range of students, selection, denomination, and for whether or not the school is in a category that receives specific types of Standards Funding.

Our dataset contains two main resource variables at school level – revenue and expenditure per pupil and pupil-staff ratios for teachers and non-teaching staff for the years 1999-00 to 2002/3. The first stage of the analysis estimated regression equations for the resourcing variables. This established, as anticipated, that resources per pupil are endogenous in that they vary positively with the percentage of pupils eligible for free school meals and with SEN and, for 2002/3, vary inversely with lagged GCSE results. The size of the school in 1999 and party political control of the local authority were statistically significant in explaining resourcing per pupil. These were consequently selected as potential instrumental variables for the estimation of pupil attainment since these variables do not directly influence the attainment of individual pupils.

The first research question addressed is the marginal effect of overall resourcing on student attainment. In both the OLS and IV specifications we found that expenditure per pupil had a statistically significant positive effect on KS3 attainment in maths and science. Consistent with this, the pupil teacher ratio had a statistically significant impact on maths and science attainment. The effects on attainment estimated using instrumental variables were up to 10 times that in the OLS regressions, indicating that studies that do not take account of the correlation between lower pupil attainment and higher resourcing per pupil due to compensatory funding will considerably underestimate resource effects. No correctly signed effect for expenditure per pupil and the pupil teacher ratio on KS3 English was found. This may be due to the larger impact of home background on English attainment and the greater importance of the quality of formal learning for maths and science attainment. In models using two instrumental variables a very small correctly signed effect of pupils per non-teaching staff on all three subjects was found, though this was not consistently significant for maths. The results for non-teaching staff are sensitive to model specification, in particular to the instruments used. The effect of the pupil teacher ratio is also smaller in regressions where pupils per non-teaching staff is assumed endogenous than in regressions where it is assumed to be exogenous.

However, all the estimated resource effects are small. Taking estimates from the single instrumental variable model, spending £100 more per pupil (ceteris paribus) would raise maths and science attainment at KS3 on average by 0.04 of a level. Reducing the pupil teacher ratio for the whole school would raise maths attainment at KS3 by just under 0.1 of a level and science by 0.12 levels. There are likely to be other outcomes, which are jointly produced with maths and science attainment, but for which we have no measures in our data set. These would also increase if revenue per pupil were higher and the pupil-teacher ratio fell. While our estimates indicate the size of the effects from marginal changes in resources per pupil, it would be unwise to extrapolate the relationship between resources and outcomes to large changes from current resourcing levels. So one cannot conclude that because we have found no resource effects for English that ceasing to employ English teachers would have no effect on pupils' attainment in English.

The second and third research questions addressed the issue of differential effects by type of student. We investigated this by running separate regressions for boys and girls, pupils with and without SEN, for different major ethnic groups, for pupils eligible and not eligible for free school meals and for quintiles by attainment at KS2 in maths, science and English combined. There were no differences in resource effects for boys or girls, for different ethnic groups or for pupils with SEN. The impact of resources on the attainment of pupils in the middle quintiles of ability was higher, in terms of the point estimates, than for those pupils in the top or bottom quintiles, but the difference was statistically significant at 5 per cent only for expenditure per pupil with respect to KS3 science. Resource effects were also greater for science for the top quintile pupils eligible for FSM (only 1 per cent of the sample) who were the only group to have positive and significant resource effects for English.

The final research question concerned resource mix effects. The only resource mix for which we have data are differences in the proportions of teaching and non-teaching staff employed per pupil. The school level regressions which included variables measuring the number of pupils per teacher, the number of pupils per support staff and the number of pupils per administrative staff indicate that controlling for revenue per pupil and size, schools with lower GCSE attainment had a higher pupil-teacher ratio and lower pupil-support staff and pupil-admin staff ratios. There is some evidence that reductions in the pupil non-teaching staff ratio are associated with higher attainment all subjects, in particular maths and English, but the effect is much smaller than that for the pupil teacher ratio and its significance is sensitive to changes in model specification. There is clear evidence that reducing the pupil teacher ratio has a small effect on attainment in maths and science. The effect of an additional £100 spent on reducing the pupil-teacher ratio has a slightly larger effect than a general increase in expenditure per pupil of the same amount. On average £100 spent on reducing the pupil teacher ratio increases KS3 maths by.07 and 0.09 levels for science compared to £100 rise in overall expenditure per pupil, which increases both subjects by 0.04 levels. There is also tentative evidence that holding the pupil teacher ratio constant, teacher quality – measured by the relative pay of teachers compared to average earnings - has a positive and significant effect on attainment in all three subjects.

Apart from resource effects, our models include a number of other variables that have a significant association with attainment. Some confirm other research findings - such as the negative impact of poverty as measured by the pupils' eligibility to free school meals and the better performance of girls in English and maths, but not science, where boys did better. Better progress between KS2 and KS3 in all three subjects was shown by pupils whose mother tongue was not English, and by those from Chinese, Indian and other Asian ethnic backgrounds. Black pupils made 0.01 level less progress in maths and science but 0.2 more in English. Living in areas with higher unemployment and greater prevalence of single parents and a poorly qualified labour force was associated with less progress at KS3 in all subjects. A pupil is further disadvantaged by attending a school with higher proportions of pupils eligible for free school meals. For example attending a school with 50 per cent FSM reduces KS3 maths and science by around 0.6 of a level compared to .06 levels if FSM is 5 per cent.

As in other studies, students in girl and boy only schools performed slightly better, and pupils in grammar schools made between 0.1 and 0.2 levels more progress. Having a sixth form depressed KS3 results slightly in maths and science. Denominational schools did no better in maths and science but did add between 0.03 and 0.06 levels more to English. This differential performance across subjects suggests that the better examination performance often claimed for faith schools relates more to pupils' home background than to the effectiveness of faith schools.

Our attempt to include an indicator of competition between schools, measured in terms of the number of schools within in a given radius of the school, was not successful. The coefficients were either insignificant or negatively signed for the number of schools within 10 km. This could well be explained by the 'competition' measure reflecting population density and so an urban or inner city location which the other variables did not control for adequately. Further research using better measures of competition is needed.

Finally, the tentative policy conclusions emerging from this study are that there are indeed positive marginal resource effects on attainment but they are rather small and subject specific, as they are present for maths and science but not for English with respect to expenditure and the pupil-teacher ratio. The marginal resource effects tend to be stronger for pupils from poor home backgrounds. Also there is some weak evidence that middle ability pupils benefit from additional spending more than pupils in the top or bottom quintiles. High ability pupils from low-income families also benefit more from higher resourcing in science. These findings suggest that rather than spread additional spending evenly, it is more effectively targeted at maths and science and at students who are of average ability or from poor homes. The evidence on the attainment effects of the pupil teacher ratio and relative teacher pay suggests directing expenditure on maintaining good quality teaching staff in relation to pupil numbers. However, due to lack of data, we did not investigate the relationship between the actual pupil staff ratios and class sizes at subject level. Our conclusions would be more persuasive if we had evidence for class size effects on subject attainment and better measures of teacher quality related to pupil attainment.

A further consideration is that these policy recommendations depend on teacher quality remaining constant or not deteriorating if real expenditure per pupil remains unchanged. However, as average earnings in the economy rise with increases in general productivity over time, it is necessary to raise teacher salaries and hence education expenditure to maintain the same real level of teacher pay. If the productivity of teachers does not increase as fast as general productivity (the 'Baumol effect'), then to maintain the same level of relative teacher pay, education expenditure per pupil has to rise without any commensurate increase in pupil attainment occurring. If relative teacher pay influences teacher quality, then it is necessary to keep relative teacher pay constant to maintain teacher quality. This study does suggest that teacher quality is related to the level of teacher salaries relative to average earnings, but the evidence is tentative because the data available for measuring relative teacher pay were rather crude.

This research demonstrates the progress that can be made in education production function research for English schools using improved datasets, which enable the problem of endogenous resources to be addressed. This study shows how misleading OLS estimates can be when resources are endogenous and that use of instrumental variables can uncover resource effects for particular subjects as well as some evidence of differences in resource effects for certain groups of pupils.

Future steps for this research would be to replicate it for other measures of attainment, in particular GCSE/GNVQ and Key Stage 2 and for other calendar years. Another improvement would be to have better controls for pupil and family background characteristics. This is becoming possible through the data gathered by the Longitudinal Survey of Young People in England in 2003, though it covers only about a quarter of the number of schools included in our study. More disaggregated data than that in PLASC, in particular at class level would enable the effects of peer groups, teachers and class size to be investigated, if suitable instruments were available. . The effect of teacher quality on attainment and the role of pay and conditions in attracting higher quality teachers deserves more extensive research in the UK context. Creating exogenous variation in resourcing through experimental trials of the application of specific additional resources to particular curriculum areas and pupil groups would permit more robust evaluation of resource effects.

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NOTES

[1] Maths and reading scores are those reported in the NCDS. Ivacou addressed endogeneity by instrumenting class size on school roll interaction with school type.

[2] Key Stage 3 national tests in English, maths and science are taken by all state school pupils towards the end of Year 9, when pupils are aged 13-14. The Key Stage 3 curriculum is taught over the first three years of secondary school, with most children transferring from primary school to start secondary school in Year 7.

[3] A vector is just a list of variables.

[4] If more detailed information on pupils' backgrounds were available it would be easier to distinguish neighbourhood effects from family effects.

[5] From 2003/4 a revised system of determining RSG was introduced. Its constituent elements are very similar to the earlier system but nomenclature changed. Education SSA is now known as Education Formula Spending Share.

[6] Age is that at 31 August before the start of the school year in September. Hence 11 year olds would become 12 in the course of the school year.

[7] This ignores some minor adjustments called scaling.

[8] AEN, up to and including 2002-03, was a composite measure using data from the 1991 Population Census of:

1. proportion of dependent children living in lone-parent households;
2. average number of dependent children claiming Income Support (a welfare benefit for the unemployed) as a proportion of residents under 18;
3. ethnicity: proportion of household residents under 16 which was born outside the UK, Ireland, the USA or the Old Commonwealth, or whose head of household was born outside these areas. (i.e. not from white English-speaking countries).

The composite AEN indicator is 2.4 times (lone parents plus Income Support claimants proportion) plus the ethnicity proportion.

[9] ACA includes two components: a general labour market adjustment for differences in wages between areas, which is the most important part, and an adjustment for business rates. It applies to London and the South East. In 2002/3 it had 13 values between 1.0622 and 1.78 which included 40% of LEAs.

[10] Only from 2004/5 was LEA discretion reduced by the DfES requiring specified increases in per pupil funding from the previous year's 'baseline' budget.

[11] There are a few secondary schools, which only admit students in Year 8 or Year 9, which is the normal year for beginning secondary school. But children study Key Stage 3 from Year 7 to Year 9 whatever type of state school they attend.

[12] The low achieving ethnic groups consist of the following ethnic categories:- Black African, Black

Caribbean, Black Other, Pakistani, Bangladeshi, "any other ethnic group" from the old codes plus mixed black and white African, mixed black and white Caribbean, any other mixed background; Asian or Asian British – Pakistani, Asian or Asian British – Bangladeshi, Mixed and white Asian, Asian or Asian British – Other, Black or Black British – Caribbean, Black or Black British – African, Black or Black British – Other, Any other ethnic group from the new codes. See DfES (2002) Technical Note on the New Education Funding System.

13 The dataset includes the easting and northing grid references of each school so that the number of competitor schools within a specified radius of each school can be calculated.

14 The total number of pupils is 5/12 of the roll in January year T plus 7/12 the roll in January year T-1.

15 There are 16 LEAs with 5% or more of their secondary schools that are middle deemed secondary schools. These are shown below.

LEA	% middle schools	LEA	% middle schools
Kirklees	22	Windsor and Maidenhead	33
Newcastle upon Tyne	38	Worcestershire	51
North Tyneside	27	Hertfordshire	7
Bedfordshire	70	Isle of Wight	76
Dorset	44	Northamptonshire	5
Poole	11	Northumberland	37
Leicestershire	17	Somerset	23
Staffordshire	20	Suffolk	26

16 Teachers' pay is top of the main scale salary. This varies according to inner and outer London and rest of England. Source: various DfES Teachers' Pay and Conditions Documents.

17 Including the Area Cost Adjustment as a regressor is unsatisfactory as it is a weight that is 1 for most LEAs and has only a few discrete values.

18 Three schools with either in excess of £5000 per annum revenue per pupil or less than £2000 were not included as they were inexplicable anomalies. One Sikh and two Muslim schools were omitted as there were too few to classify under separate denominational categories.

19 Heteroscedasticity is non-constant variance of the error term in the regression equation.

20 The SSA for education is an indicator of the educational need in a particular LEA. It is positively correlated with the amount of Revenue Support Grant received.

21 We did not use the LEA's expenditure per secondary pupil as an instrument because it has the same weakness as SSA in that it is correlated with pupil attainment to some extent and in addition is dependent on the political control variable, which is used as an instrument.

22 For pupils per non-teaching staff we found evidence of endogeneity using the political control and school size instrumental variables but not when using political control and SSA as instruments.

23 Our results when we used both the political instrument and the school size instrument were qualitatively similar to those obtained using just the political variables, although the coefficient on the expenditure per pupil variable was somewhat smaller in this instance (around 0.0002 for Mathematics and Science, as compared to just under 0.0004).

24 For example a pupil born at the end of February would obtain 3% of a level more in maths than one born at the beginning of September.

25 Capturing peer group effects by including the average KS2 attainment level of the year group in maths, English and science was investigated but when included with the percentage of students eligible for free school meals with which it is highly correlated, the average KS2 score variable was wrongly signed. It was therefore not included in the estimated models reported here.

26 Tests suggest that the differences between quintiles, both for maths and for science, are not statistically significant at the 5% level but are at 15%.