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SCHOOL CHOICE, COMPETITION AND THE EFFICIENCY OF SECONDARY SCHOOLS IN ENGLAND

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ABSTRACT

In this paper we calculate the technical efficiencies, based upon multiple outputs - school exam performance and attendance rates - of all secondary schools in England over the period 1993-97. We then estimate models to examine the determinants of efficiency in a particular year, and the determinants of the change in efficiency over the period. Our results suggest that the greater the degree of competition between schools the more efficient they are. The strength of this effect has also increased over time which is consistent with the evolution of the quasi-market in secondary education. Competition is also found to be an important determinant of the change in efficiency over time. There is, however, some evidence of conditional convergence between schools.

INTRODUCTION

The election of a Labour Government in 1997 has rekindled the debate about the quality of secondary schooling in the UK. A recent White Paper proposes the introduction of Education Action Zones in the most deprived areas of the country to increase equality of opportunity (D*f*EE, 1997). However, raising the educational performance of pupils is to be achieved primarily through improvements in individual schools rather than through a radical transformation of the education system. In fact, the so-called quasi-market in secondary education, initiated by the previous Conservative administration, will be left virtually intact (see Section II).

The need to raise educational standards in secondary schools is clearly important because a large stock of poorly educated and unqualified workers has a number of macroeconomic effects, such as lower productivity and growth (Prais, 1995; O'Mahoney, 1998). There have been numerous microeconometric studies which have also shown that a poor education decreases the probability of obtaining employment, reduces the chance of acquiring vocational skills and leads to lower lifetime earnings (Andrews and Bradley, 1997; Green, 1993 and Makepeace, 1994).

The Labour Government takes the view that a poor education traps individuals and families in a cycle of deprivation and poverty (D*f*EE, 1997). Poor performance at school leads to labour market disadvantage which places the individual at greater risk of poverty, and potentially to the transmission of negative attitudes towards education between successive generations (see Social Exclusion Unit, 1998; Home Office, 1997). Moreover, the Home Office report lists poor discipline at school, truancy and exclusion as key factors which determine youth crime.[1] One possible way of breaking the cycle of deprivation is to simultaneously raise exam performance and change the attitude of pupils and parents to schooling. Consequently, schools must pay due attention to their exam performance and their attendance record since both can result in economic and social benefits.

This paper has two broad aims. The first is to measure the efficiency of all secondary schools in England in terms of the joint maximisation of exam performance and the attendance rate (one minus the truancy rate), given various inputs. Because we have panel data on school performance, we are also able to observe how school efficiency has changed over time. Secondly, we seek to explain in a regression framework variations in efficiency between schools at several points in time (1993 to 1998), and the change in efficiency over the period. The regressors used in the second stage of the analysis refer to the type of school, the extent of competition between schools in the catchment area, local environmental variables, including the unemployment rate, and Local Education Authority (LEA) expenditure on teachers and books. The results of our analysis have particular relevance to the current debate about school performance, the determination of Educational Action Zones and education policy in general. Furthermore, our own work represents an advance on previous work in that we measure and then seek to explain the relative efficiency of *all* secondary schools in England. Previous work has either been highly aggregated, focusing upon the efficiency of LEAs, or has adopted a case study approach based upon schools within a limited geographical area (see Table 1). Our approach also pays full attention to the view that schools are multi-product organisations who may therefore be successful, or efficient, in a variety of ways.

The paper is organised as follows. In section I we discuss the changes to the secondary school sector over the last 15 to 20 years, paying particular attention to the way in which the quasi-market has evolved. This is followed in Section II by a description of the methodology used for measuring the efficiency of each school and the econometric approach adopted for the analysis of the determinants of efficiency. Dovetailed into this discussion is a detailed review of the relevant literature. In section III we describe the data used in the analysis and illustrate how efficiency varies with school and local environmental characteristics. Section IV presents our econometric results. We end with our conclusions.

I. THE EMERGENCE OF THE QUASI-MARKET

The thrust of education policy over the last 15 years or more has been to create a so-called quasi-market in secondary education. Various reforms, culminating in 1988 with the implementation of a major piece of legislation, the Education Reform Act (ERA), have meant that schools are now in direct competition for pupils (Le Grand, 1991; Bartlett, 1993). School choice was increased by giving parents greater freedom to choose between secondary schools. Good schools are expected to grow in size and flourish, whereas poor schools would either wither and close, or react by introducing strategies to raise performance. The logic underpinning the quasi-market is therefore that the increase in competition between schools will lead to an overall improvement in the quality of education provision, especially in terms of examination results.

To facilitate the creation of a quasi-market, several initiatives were introduced which affected both the providers of education (i.e. schools - the supply-side) and the consumers of educational services (i.e. parents and pupils - the demand-side). On the supply-side the mix of school types was changed with the introduction of Grant Maintained schools and City Technology Colleges, both of which are outside of the control of the LEA. All school managers were given greater freedom over the allocation of their resources with the introduction of the Local Management of Schools (LMS) initiative. Schools now have a management team responsible for school finance and strategy. The LMS initiative has forced schools to become more efficient in the use of resources, and has also made them more responsive to consumers (Jackson 1994). Acting as a check upon school autonomy, 'parent-power' has increased within schools via the governing body. Parents now have a greater impact upon teacher recruitment, resource allocation and curriculum content than was hitherto the case.

The introduction of open-enrolment has changed the demand side of the market by affording parents greater power in the choice of secondary school. Prior to the reforms, the LEA had the prime responsibility for allocating pupils to schools to ensure a minimum level of resource utilisation, which in effect meant that the less popular schools were ensured a share of the pupil population. Parents also found their children being channelled, sometimes against their will, to less popular schools even though places were available at the school of first choice. A policy of open enrolment means that good schools are now able to increase their share of the pupil population subject only to the contraints imposed by their short-run physical capacity[2]. This has been reinforced by the introduction of formula funding whereby money now follows pupils, and is calculated primarily on the basis of an age-weighted school population (Bartlett 1993, Jackson 1994). School managers therefore have a financial incentive to increase their pupil numbers and so the school's market share.[3] Furthermore, non-selective schools facing an excess demand for places may respond by creaming off the best applicants to maintain their exam performance (see Millington and Bradley, 1998 and Bradley *et al*, 1999). Increasing parental choice has necessitated an increase in the quantity and quality of information on school performance. This has been provided through the annual publication of the School Performance Tables by the Department for Education and Employment (D*f*EE). Each school's performance in public examinations and on measures of truancy are highlighted.

The reforms to the secondary school sector have removed the barriers to, and increased the incentives for, competition between schools. However, schools may see the relationship between exam performance and attendance as a trade-off. Schools may therefore compete in a two-dimensional space, the quality of their output being measured by both attendance and exam performance. The School Performance Tables have focused parental attention upon the upper end of the GCSE exam distribution, in particular the proportion of 5 or more A*-C grades, which may have led some schools to give less attention to pupils at the lower end of the distribution. This may lead to higher truancy rates, because of lower levels of monitoring, and the worst offenders may be discouraged from registering for exams or be excluded from school. In this scenario attendance rates may fall but exam performance may appear to rise.

Figures 1a and 1b show the relationship between exam performance and truancy. They suggest that schools who wish to achieve high exam performance may do so by increasing the attendance rate, since those schools with a high truancy rate have much lower exam performance. This runs counter to the view that a trade-off exists.[4] A joint maximising strategy is therefore preferable. Figure 2 plots the relationship between examination performance and the exclusion rate. There is little evidence that the best performing schools exclude pupils to improve their published exam performance in the school league tables. As one might expect, the schools with the lowest exam performance have the highest exclusion rates. [5]

In view of this, it is pertinent to ask two questions. First, which schools are most efficient at maximising (some summary measure of) exam performance and the attendance rate? Secondly, what factors determine that efficiency?

II. METHODOLOGY

Economists typically view educational outcomes as a function of a variety of school inputs, including school expenditures, pupil-teacher ratios, teacher experience, the prior attainment of pupils, peer group pressures and family background (Hanushek, 1976, 1992). However, there has been limited success in finding a causal link between school inputs and educational outcomes. Early work on the education production function concluded that ‘teachers and schools differ dramatically in their effectiveness’ but that there is ‘no strong or systematic relationship between school expenditures and student performance’ (Hanushek, 1976, p.1159 and p.1162). The result that pupil-teacher ratios do not negatively affect performance is counterintuitive (Correa, 1993), but has proved to be remarkably robust (Betts, 1995; Akerhielm, 1995).[6] However, Bradley and Taylor (1998) do find a consistent, positive, effect of *school* size on exam performance, after controlling for a large number of school inputs and pupil characteristics. Millington and Bradley (1998) also show that the greater the degree of competition between non-selective secondary schools, the higher a school's exam performance. The presence of selective schools in the catchment area depresses the exam performance of non-selective schools because they admit the most able pupils. This is the so-called cream-skimming effect.

Previous research has also shown that pupil characteristics, such as gender and innate ability (Feinstein and Symons, 1997), socio-economic background (Coleman Report, 1966; Rutter *et al*, 1979; Feinstein and Symons, 1997) and family size (Loeb and Bound, 1996) tend to have a greater effect on exam performance than school inputs. Girls, pupils from smaller families and high income families tend to perform better in exams. Peer groups also exert an effect on performance through the transmission of academic values (Robertson and Symons, 1996).

Relatively little research has been undertaken on the determinants of truancy. Bosworth (1994) does show, however, that the propensity to truant is greater than it otherwise would be if the pupil is male, has many siblings, or comes from a socially or economically disadvantaged family. In addition, the availability of career advice and attitudes to school, both of which are likely to be endogenous variables, appear to have a plausible effect on truancy.

Closely related to the analysis of education production is the analysis of education costs, which is viewed as the dual of the production function. Early work on this focused upon single-school districts (Riew, 1966 and Cohn, 1968) but more recent studies emphasise the multi-product nature of educational institutions (for instance, Cohn *et al*., 1989 and de Groot *et al*., 1991). Multi-product cost functions are usually estimated using OLS, though the most recent studies employ stochastic frontier methods (for instance, Johnes, 1998). This is because the production and cost functions of theory are constructed on the premise that technical inefficiency is absent, which is not the case in practice.[7]

The stochastic production frontier method (Aigner *et al*., 1977) has the drawback that it can only deal with single outputs, but has over OLS the advantage of dividing the error term into two components; measurement error and technical inefficiency. This parametric approach poses a number of problems in the context of an education production (or cost) function. In particular, and as the cost function literature suggests, schools cannot legitimately be said to produce just one output. Moreover, the multiplicity of outputs produced by a school cannot be aggregated into a single measure in any meaningful way. While a multi-product profit maximising firm in a competitive industry can use market prices as weights in aggregating its costs and revenues, a school is neither profit maximising nor fully competitive, and market prices are inevitably absent. In this context, an alternative to parametric frontier models, namely data envelopment analysis (DEA) provides an attractive means of locating the production possibility frontier and hence evaluating the technical efficiency of schools.

In common with parametric frontier models, DEA has its roots in the work of Farrell (1957). But the seminal contribution is that of Charnes *et al.* (1978). Since then, the use of the method has become increasingly widespread, and applications have recently migrated from the operational research literature into mainstream economics.[8]

The simplest variant of DEA is a constant returns to scale model in which n decision-making units produce s distinct output types using m distinct inputs. The quantities of outputs and inputs which the kth decision-making unit produces and consumes respectively are denoted by Y_{rk}, r = 1, ... , s, and X_{ik}, i = 1, ... , m. The kth decision making unit then chooses its vector of input weights, v_{ik}, i = 1, ... , m, and output weights, u_{rk}, r = 1, ... , s, with the aim of maximising its weighted sum of outputs subject to a number of constraints. These are that: (i) the chosen weights are such that, when applied to the output and input vectors of *any* decision-making unit, the ratio of weighted output to weighted input should not exceed unity, (ii) the weighted sum of inputs should equal unity, (iii) the weight attached to each output should be non-negative, and (iv) the weight attached to each input should be non-negative. Now this is a fairly simple linear programming problem. The complete specification of a DEA involves the simultaneous solution of n such programmes - one for each decision-making unit.

The above arguments may be represented by a suite of linear programming problems. Formally, for each k,

$$\max h_k = \sum_{r=1}^{s} u_{rk} Y_{rk} \tag{1}$$

subject to

$$\sum_{r=1}^{s} u_{rk} Y_{rj} - \sum_{i=1}^{m} v_{ik} X_{ij} \leq 0 \; ; j = 1, \ldots , n \tag{2}$$

$$\sum_{i=1}^{m} v_{ik} X_{ik} = 1$$

$u_{rk} \geq 0$; r = 1, ... , s

$v_{ik} \geq 0$; i = 1, ... , m

The optimal value of h_k is the efficiency score of the kth decision-making unit. It must lie between zero and one; if $h_k = 1$, then k is technically efficient and lies on the efficiency frontier. As specified above, the DEA problem is one of output maximisation. The corresponding input minimisation problem can be constructed by analogous means.

In this paper we obtain the technical efficiencies for each school by specifying a constant returns to scale, output maximisation model with radial objectives.[9] [10] The non-parametric nature of DEA has a number of implications which ought to be emphasised at this stage. First, the standard battery of statistical tests is not available.[11] Second, the weights which are assigned to the inputs and outputs in the evaluation of technical efficiency are specific to each observation in the sample; that is, each decision-making unit (in the present case, each school) is allowed to determine the weight vector which maximises its technical efficiency score when these weights are applied to each of the decision-making units in the sample. In effect, the method gives each school the licence to set its own goals and to be judged in accordance with these goals, not according to some exogenously imposed parameters. This licence accounts for the considerable appeal of DEA when applied in multi-input multi-output contexts without readily observable market prices.[12] Moreover, the comparison of (multiple) inputs with (multiple) outputs, which is the cornerstone of DEA, allows the efficiencies evaluated by this method to be given a value-added interpretation.

Applications of DEA in the context of the evaluation of education providers in the primary and secondary sectors are surveyed in Table 1. In the UK, analyses of the secondary sector have taken two forms. One type of study involves the evaluation of schools within a single Local Education Authority (LEA). Examples of this are provided by Norman and Stoker (1991) and Thanassoulis and Dunstan (1994). These two studies are unusual in that, in each case, one of the outputs on which the DEA is based is a labour market outcome, namely a measure of the employability of leavers. In the present study, one of the outputs is the attendance rate of pupils; low rates of truancy are supposed to be characteristic of schools which instil in their pupils a sense of social responsibility. We are not aware of any previous studies which have included this output.

The second group of studies is based on an analysis of the efficiency of LEAs, cast in terms of the output of secondary schools within their jurisdiction. Most of these are older studies, conducted using data which preceded many of the recent reforms in the administrative structure of compulsory education. Hence their usefulness is diminished. Nevertheless, it could be argued that to conduct the exercise at LEA level is inappropriate in that this represents too high a level of aggregation – a British LEA typically comprises many more schools than an American school district, and it is presumably at the level of the school that the greatest inefficiencies in the use of resources are likely to occur. In the UK, adequate school level data only became available with the introduction of published performance indicators from 1993. The present paper constitutes the first attempt to evaluate, at the appropriate level of aggregation, the determinants of technical efficiency of state secondary schools throughout the country.

The results of any DEA are likely to be sensitive to the choice of inputs and outputs used. In view of the large number of observations (decision-making units) used in the present study, the specification of inputs and outputs has to be fairly parsimonious so that the computational burden remains manageable.[13] The studies summarised in Table 1 have a number of features in common which allow us to infer which inputs and outputs ought to be included in the specification of the model. Outputs of the education system typically include some measure of examination success, but also in some specifications includes other measures such as pupils' subsequent labour market performance. Inputs characteristically include measures of pupil composition such as ability on entry and socio-economic characteristics. In addition, measures of resourcing are often included, such as pupil-teacher ratio, educational expenditure, and the quality of the teaching staff.

In four studies - Ray (1991), Lovell *et al*. (1995), Kirjavainen and Loikkanen (1998) and Mancebon and Mar Molinero (1998) - the exercise is conducted in two stages. In the first stage, DEA efficiencies are evaluated, while in the second these same efficiencies are explained in a regression analysis. The present paper pursues this approach too. An issue then revolves around the decision concerning which variables to include in the DEA itself, and which should be reserved for use in the regression analysis. Ray reserves environmental variables for the latter and school variables for the former. The remaining studies, like ours, do not confine their interest at the second stage to variables beyond the control of the school itself. The study by Kirjavainen and Loikkanen is especially notable for two reasons; first, the use of Tobit as the estimation method in the second stage, and secondly the use of a jackknife to evaluate the robustness of the DEA efficiencies.

The DEA technique produces measures of efficiency which are bounded between 0 and 100, and this has implications for the methodology which we shall employ in the second stage of our analysis. While some authors have eschewed the use of limited dependent variable methods in this context, we prefer to estimate a tobit model of the determinants of school efficiency. Following Maddala (1987), the model can be written as in (3)

$$y_i^* = \beta' x_i + u_i$$

where y_i^* is a latent variable referring to the technical efficiency of schools. However, what we actually observe in the data is given by equation (4)

$$y_i = L_{1i} \;\; if\, y_i \leq L_{1i}$$
$$y_i = y_i^* \;\; if\; L_{1i} < y_i^* < L_{2i}$$
$$y_i = L_{2i} \;\; if\, y_i^* \leq L_{2i}$$

L_{2i} and L_{1i} are the upper and lower limits of the data. In practice, we have no observations at the lower limit and so we estimate a right censored tobit model using maximum likelihood techniques in Stata.

III. THE DATA

The data used in this study are drawn from four sources. First, the School Performance Tables, published annually by the D*f*EE since 1992, which include exam results and truancy rates.[14] Second, unpublished annual *Schools' Census (Form 7)* data which were provided by the D*f*EE, and contain information on the pupil-teacher ratio, school type and the socio-economic background of pupils. Third, data referring to LEA expenditure on books and materials and on teachers were also obtained from the D*f*EE. Fourthly, local environmental data, such as the unemployment rate and socio-economic composition of each Local Authority District (LAD) level were extracted from the National Online Manpower Information Service. A full list of the variables used in the statistical analysis, together with some descriptive statistics, is provided in the appendix. Special schools are excluded from our analysis because their pupils typically do not sit public examinations. Selective grammar schools are excluded from the sample but a set of covariates are included to capture cream skimming effects within the local education market. In addition we exclude schools for which no attendance data are available, so that we are left with a sample of 2657 schools.

In our specification of the DEA problem, we impose constant returns to scale. This allows parsimonious specification of the linear programmes, and permits us to explore scale factors during the second (tobit) stage of the analysis. In order fully to exploit the non-parametric properties of the method, radial objectives are invoked. To be more specific about the model being evaluated, there are two outputs - the proportion of 5+ GCSEs grades A*-C (EXAM) and attendance rate (ATTEND) - and two inputs - the proportion of pupils ineligible for free school meals (INELIG) and the proportion of qualified teachers (QUALST). It is assumed that each school will seek to maximise their outputs given their inputs, which reflect the quality of the raw material (i.e. pupils) and the quality of the labour input (i.e. teachers).[15]

In the tobit analysis, the x vector in equation (3) can be divided into five groups. Firstly, schools are distinguished according to the extent to which they are independent of local authority control (TYPE). Grant-maintained schools are at one end of the spectrum, completely independent of LEA control, whereas county schools (the base group) are subject to substantial LEA interference. Other types of school lie between these two extremes. Secondly, a set of variables are included to capture the degree of competition between non-selective schools. This is constructed by counting the number of schools between two radii centred around a given school, for instance within a 1 kilometre radius, 1-2 kilometres and so on up to 3-5 kilometres (COMP).[16] We also allow for the presence and proximity of selective schools since they may cream skim the market, leaving the less able and less motivated for non-selective schools, whose efficiency is thereby reduced. Thirdly, two variables are included to capture the gender composition of the school (GENDER), since previous studies have shown that girls-only schools typically enjoy better average performance in exams than mixed groups (Bradley *et al*, 1999). Single sex schools may therefore be more technically efficient. Fourthly, a number of variables are included to capture the local environment in which the school is located (ENVIRON). Population density is included to capture a rural-urban effect on technical efficiency. The local unemployment rate could raise or lower efficiency depending upon its impact upon pupil and teacher motivation. Schools located in areas with a high proportion of professional and managerial workers are likely to be more efficient insofar as greater financial and other support is forthcoming for the pupil outside of school. There may also be a greater 'voice effect' in these localities, insofar as middle class parents exert greater pressure on a school to perform well. Fifthly, LEA and school resource variables are included in the model (RESOURCE). Expenditure on teachers and books are included, and both are measured per pupil at the LEA level. This variable captures LEA policy towards the schools over which it has control. It is expected that the higher the level of expenditure on teachers the more efficient the school is likely to be because of efficiency wage arguments. Expenditure on books should raise efficiency through its effect on exam performance. The size of the school is included to allow for scale economies (Bradley and Taylor, 1998), whereas the pupil-teacher ratio is included since larger average class sizes may reduce efficiency because the teacher is spread more thinly.[17]

IV. RESULTS

Measurement of school efficiency

Table 2 provides summary statistics for each of the 8 schools obtaining the lowest DEA efficiency scores in 1993, and also for each of the 8 schools obtaining the highest scores.[18] These are instructive, not least because they show very forcefully that there is more than one way to be efficient. School 2 has a high proportion of pupils achieving success at GCSE. The corresponding proportion for School 4 is very low - indeed it is exceeded by most of the bottom 8 schools. But School 4 is nevertheless technically efficient because one of its inputs, the proportion of qualified staff is also very low.[19] Similarly, school 6 is efficient in spite of a low GCSE score because the proportion of pupils ineligible for free school meals is very low. This means that school 6 recruits pupils primarily from the lower end of the socio-economic heirarchy and they are likely to have lower educational attainment on entry. Likewise, there is more than one way to be inefficient: the relatively poor performance of School 2652 owes much to a relatively high truancy rate, while that of School 2650 is clearly due in large measure to poor examination performance.

Only one of the schools which appear in the top 8 in 1993 remains technically efficient in 1997. This is not altogether surprising, and does not necessarily reflect a decline in absolute performance.[20] Of those in the bottom 8 in 1993, virtually all schools improved their relative performance. Again, this is unsurprising. It is easier to make gains where most gains remain to be made. There is a clear error-correction type of mechanism at work here, and this is something which we shall investigate more formally later in the paper when we control for fixed effects.

We have already discussed the controversy in the literature concerning the relationship between school performance and school inputs, and in particular the role played by the pupil-teacher ratio. The data reported in Table 2 suggest that there is no clear cut relationship between the pupil-teacher ratio and the efficiency of the school.[21] In the analysis which follows, we shall investigate this relationship in some depth, focusing in particular on non-linearities in the data, and on the issues of endogeneity and unobserved heterogeneity.

A popular notion concerning differences in school performance is that environmental factors dominate. Our data suggest that this is not the case. The local unemployment rate in 1993 was above average for 5 of the top 8 schools, but the exam performance of their pupils differed substantially. Furthermore, most of the bottom 8 schools were in also in areas which had higher than average unemployment rates.[22]

To test the robustness of the efficiency scores obtained from DEA we performed a form of sensitivity analysis known as 'jackknifing' (Kirjavainen and Loikkanen, 1998). Each observation with an efficiency score of 100 is dropped in sequence, without replacement, and the DEA model is then re-estimated. The correlation between the efficiency scores is then calculated. Clearly, this is one way of checking the influence of outliers which lie on the frontier, an example of which is school 4 in Table 2. The results of this exercise suggest a high level of correlation between the efficiency scores, with a range from 0.836 to 0.998 for 1993. We conclude, therefore, that the efficiency scores are robust.

The determinants of school efficiency

In this section we begin by discussing the cross-sectional results from the tobit models, and focus upon the way in which the coefficients change through time as the quasi-market takes hold. This is then followed by a discussion of the determinants of the change in efficiency over the 1993-97 time period.[23] The conceptual question addressed here is: are schools in 1997 relatively more efficient compared to their peers than they were in 1993? Thus the focus is upon relative rather than absolute changes in efficiency. To obtain a picture of the extent of absolute change in school efficiency we pool our data 1993 and 1997, and then re-estimate our DEA model.

Table 3 shows the results for the tobit models. These are estimated using data for all schools, with DEA efficiency as the dependent variable. The competition variables have the expected effect, so that schools facing greater competition from non-selective schools tend to be more efficient.[24] This effect picks up over time as quasi-market forces take hold. Also, within any one year, it is competition from the most immediate rivals that has the greatest effect on efficiency. In 1997, for instance, the coefficient on R1, which refers to rivals in the immediate proximity of a school, is six times greater than that on R35 - rivals in the wider area.[25] There is little systematic evidence that cream skimming by selective schools reduces the efficiency of non-selective schools. Although the coefficients are negative, as expected, they are generally insignificant.

The effect of school type on efficiency is strong. A consistent finding is that secondary modern schools are less efficient compared to county schools, although the strength of this effect fluctuates over time. In contrast, voluntary and grant maintained schools, who typically generate resources from a wider number of sources, are far more efficient than county schools. Their greater efficiency may be due to the discretion that such schools are allowed to select a small proportion of their intake on academic criteria; further it may reflect the fact that such schools cannot rely on the safety net provided by the LEA to the same extent as county schools. All-girl schools are considerably more efficient than co-educational schools, whereas there is no statistically significant effect for boys. Given inputs, girls in all-girl schools therefore perform better in exams and truant less on average, which may reflect differences in school ethos, discipline and organisation, or it may be that girls are simply 'better' pupils.

Local environmental variables also exert a strong influence upon school efficiency. Our results suggest that, after controlling for the quality of staff, pupils and the other variables included in the tobit model, the higher the local unemployment rate the greater the *relative* efficiency of a school. This is, at first blush, a counterintuitive result. We suspect that it is a consequence of the DEA specification which we have chosen. To be specific, high unemployment areas are likely to have a high proportion of children in receipt of free school meals. Hence one of the inputs to schools in these areas is unusually low. Since the weights assigned to the various inputs and outputs are school-specific, the high efficiency score obtained by many schools in high unemployment areas likely reflects the fact that, for such schools, the weight attached to the proportion of children not on free school meals is unusually high - thus allowing these schools to achieve a high efficiency score. This finding allows us to emphasise once more the interpretation of DEA efficiencies as value added indicators. However, it is also the case that schools in areas with a higher proportion of professional and managerial workers are also more efficient. Pupils from this type of family background may receive greater support for their education outside of school, insofar as extra resources and a more conducive learning environment is provided. To the extent that these parents also take a greater interest in the education of their children, they may be less likely to truant.

A key issue is whether resources have any effect upon the efficiency of secondary schools. Expenditure on teachers, rather than buildings or administrators, does raise efficiency, although the effect is quite small throughout the time period. In comparison, expenditure on books per student is generally insignificant.

The higher the pupil-teacher ratio the lower the efficiency score might be expected to be because class sizes may rise, thereby reducing the amount of contact between the teacher and individual pupils. This may then reduce attainment and, if the costs of monitoring attendance rise, then the truancy rate may increase.[26] However, over time good schools are likely to attract more and better quality pupils, and so the pupil-teacher ratio is endogenous. To overcome this problem we instrument the pupil-teacher ratio using the lagged exam performance of the school, school type and other school level variables. The early results are mixed, sometimes positive and and sometimes zero, which is in agreement with much early work (Hanushek, 1995). However, by the end of the study period the pupil-teacher ratio is negative and significant, as expected, suggesting that schools with larger average class sizes were less efficient. As a further test we explored the possibility that the link between the pupil-teacher ratio and efficiency might be nonlinear by including the square of the former as further regessor in the model. The coefficient estimates which resulted suggested that a turning point exists but that the second derivative is positive – that is, the relationship between pupil-teacher ratio and efficiency is, implausibly, U-shaped. This puzzling result implies that the model is not correctly specified as a quadratic, and we therefore prefer the linear version of the pupil-teacher ratio variable.[27]

Previous research has suggested that larger schools have better exam performance. However, larger schools may also find it more difficult to monitor the attendance of individual pupils which may then translate into a higher truancy rate. The effect of school size on efficiency therefore depends on the net effect of these two influences. Our results show that school size had a small positive and stable effect on efficiency throughout the period.

A more demanding test of the effect of competition, and other variables, on school efficiency, is to examine their effect on the change in efficiency over the 1993-98 time period. The results of this exercise are shown in Table 4. The effect of competition from non-selective rival schools on efficiency remains strong and works in the expected direction. More proximate rivals exert a stronger effect on efficiency compared to their more distant rivals. Compared to county schools, grant maintained and voluntary assisted schools have experienced the greatest increase in relative efficiency, which may be a reflection of their greater independence over resource allocation and admissions policies.[28] LEAs that have increased their spending on teachers the most have also witnessed a small positive increase in relative efficiency, whereas there is no effect from the change in book expenditure per pupil. As expected, the change in the pupil-teacher ratio is negative whereas the change in school size is positive.

Finally, we include the initial value of technical efficiency (i.e. for 1993) in the model to test for the possibility of convergence in efficiency over the period. As the quasi-market has evolved there is clear evidence of convergence in the *relative* efficiencies of schools. Of course, this does not mean that schools have increased their efficiency in absolute terms. To test for this we pool the data for 1993 and 1997 and re-estimate the DEA model. The results of this exercise suggest that absolute efficiency has increased over the period: the mean change is 1.3% with a standard deviation of 3.1%).

Figure 3 plots the change in efficiency between 1993 and 1998 against the initial (1993) level of technical efficiency. The graph is striking in two respects. First, the scatter plot is suggestive of a downward sloping relationship which implies that those schools with the lowest relative efficiencies in 1993 tended to gain most in efficiency over the period; this confirms that there has been some degree of convergence over time in the performance of schools. Second, there is a marked bunching of observations somewhat above zero on the vertical axis. Overall efficiency appears to have improved in absolute terms over the period.

V. CONCLUSION

The emergence of a quasi-market in secondary education has simultaneously given parents greater school choice and increased competition for pupils between schools. Recent official publications have suggested that raising the performance of the education system should be undertaken through individual schools, rather than through any systematic reform of the sector. Current debate revolves around the need to improve exam performance and reduce truancy because failing to do so will have detrimental economic and social consequences.

In this paper we have used a unique panel data set covering all secondary schools in England to calculate their technical efficiency. Using non-parametric techniques, schools were allowed to jointly maximise multiple outputs, notably their exam performance and attendance rate. Not surprisingly, the results show that there is more than one way to be efficient. There is also evidence that the least efficient schools in 1993 have improved the most over the time period (1993-97) as the quasi-market developed. These findings have implications for the designation of Education Action Zones, insofar as it is possible to identify clusters of inefficient schools, and for identifying good practice.

Perhaps more importantly, we have also tried to identify those factors which determine school efficiency over a sequence of years (1993 to 1997) and the change in efficiency over the period. The results of this exercise are revealing. A particularly important finding is that, the greater the degree of competition between schools, the more efficient schools tend to become. Moreover, differentials in efficiency between the most and least efficient schools appear to narrow in response to competition. These effects have strengthened over time, a finding which is consistent with the evolution of the quasi-market. Competition between schools is also found to be an important determinant of the *change* in relative efficiency over time. One implication of these results is that policymakers should take care when deciding whether to close a particular school, since the gains from reduced public expenditure may be outweighed by the loss of efficiency in neighbouring schools because of the reduction in competition between schools.

Other results reported in detail above also have policy implications. In particular, we found some support for the notion that the pupil-teacher ratio negatively affects school performance. This is an important result which runs counter to the findings of most previous research on educational production functions.

Changes in schools' relative efficiency were found to depend positively on changes in local spending on teachers. Spending on books and related equipment also has a positive effect, but our findings suggest that this is much smaller (and less significant) than that of expenditure on teachers. We would speculate that the impact of expenditure on teachers might become much stronger once the new policy of incentive-based payments to 'super-teachers' takes effect.

In common with other studies and much media comment, we have established that girls-only schools typically perform better than otherwise similar institutions. Our findings on local labour market conditions are somewhat difficult to interpret: a high incidence of local unemployment appears to raise school efficiency, but so does a highly middle class local population. Some collinearity doubtless remains in our environmental regressors.

Finally, we would argue that one aspect of our present study provides unusually compelling evidence on an important policy issue: the policy of parental choice which successive UK governments have adopted over the last decade is serving significantly to enhance the efficiency of secondary education in England.

Figure 1a Relationship between GCSE exam performance and truancy rates 1998.

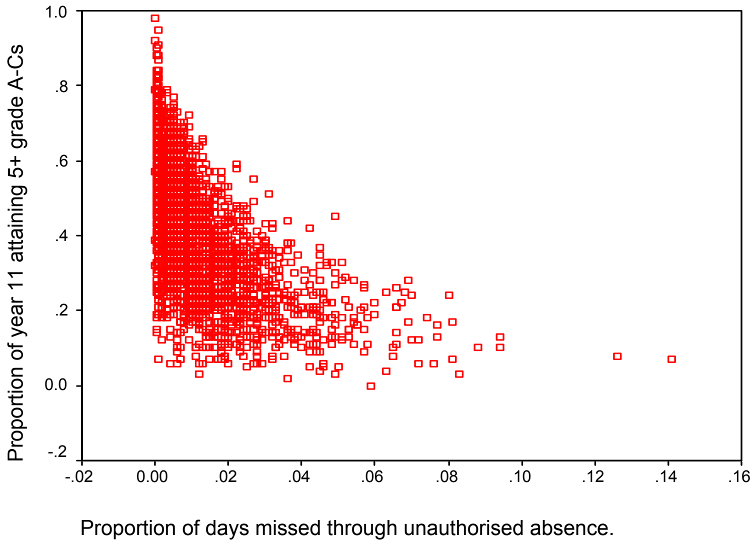

Figure 1b Relationship between exam performance and truancy rates 1993.

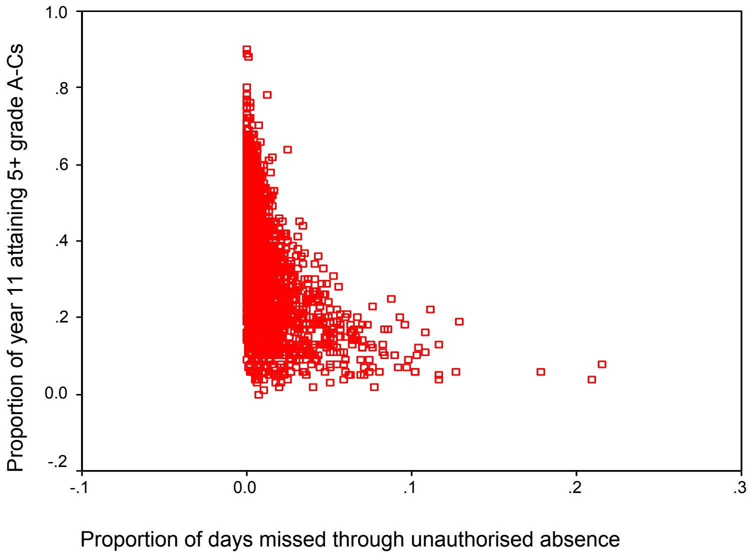

Figure 2 Relationship between GCSE exam performance and the exclusion rate 1997

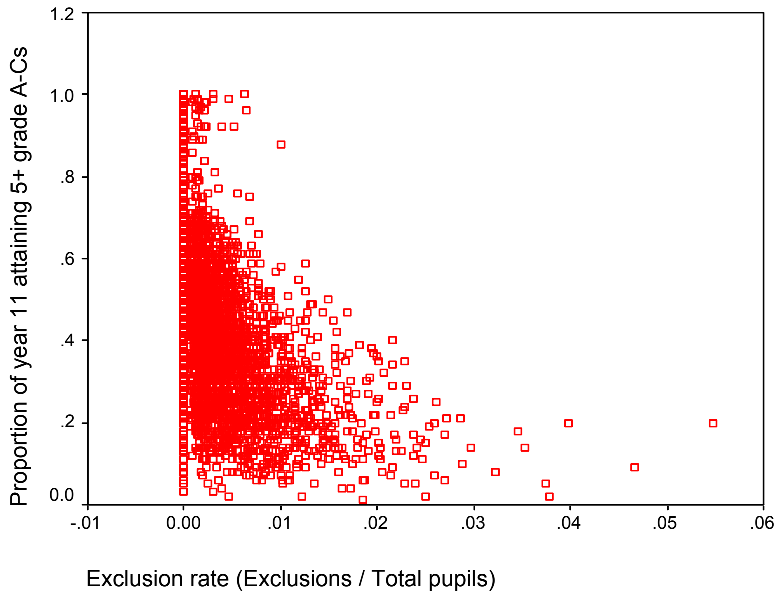

Figure 3 Change in absolute efficiency 1993-1998

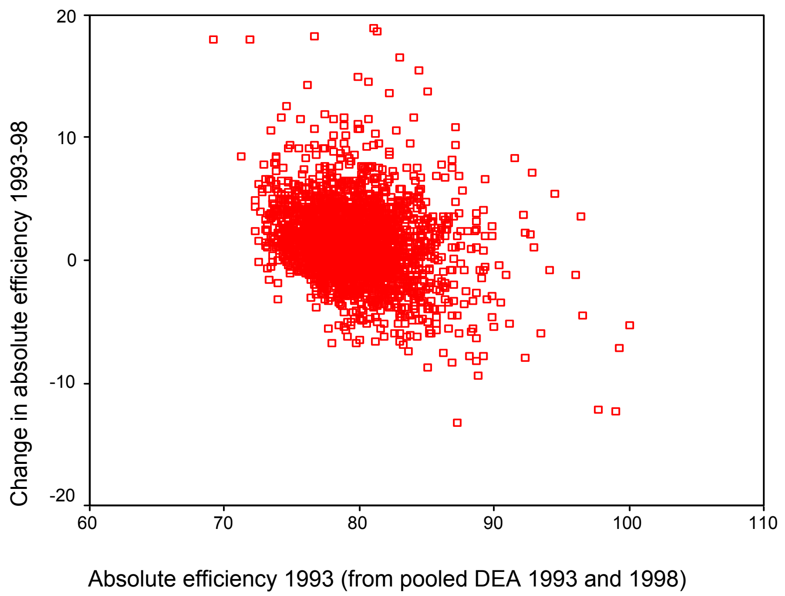

Table 1 A Review of Data Envelopment Analyses of Primary and Secondary Schooling

	sector	coverage	inputs	outputs	comments
Bessent & Bessent (1980)	elementary	schools in one school district	•median percentile reading test score of pupils 11 years earlier •median percentile mathematics test score of pupils 11 years earlier •% Anglo-American •% not from low income households •attendance rate •mobility index professional staff per pupil •instructional expenditure per pupil •job satisfaction of teachers •social interaction amongst teachers •motivation of teachers and principal •friendliness of principal •index of teaching methods (ranging from group teaching to individualism)	•median percentile reading test score of pupils •median percentile mathematics score of pupils	numerous qualitative variables used as inputs
Bessent *et al.* (1982)	elementary	schools in Houston	•mean ITBS score at 2nd grade •mean ITBS score at 5th grade •% non-minority •% paying full lunch price •attendance rate •number of professionals employed per pupil •local and state expenditure per pupil •federal expenditure per pupil •number of special programmes in school •% teachers with masters degree •% teachers > 3 yrs experience •teacher attendance rate	•mean ITBS score at 3rd grade •mean ITBS score at 6th grade	

Chalos & Cherian (1995)	Elementary	school districts in Illinois	●% pupils not low income ●% pupils non-minority ●pupil attendance rate ●operating expenditure per pupil ●% teachers with masters degree	●mean mathematics IGAP score level 6 ●mean mathematics IGAP score level 8 ●mean verbal IGAP score level 6 ●mean verbal IGAP score level 8	
Färe *et al.* (1989)	School districts at 8th grade	40 school districts in St Louis, Missouri	●number of 8th graders taking BEST test●net current expenditure ●net assessed valuation ●number of 8th grade teachers	BEST 8th grade test results in each of: ●reading ●mathematics ●economics & government	use variable returns to scale specification and jackknifing to provide statistical inference
Ganley & Cubbin (1992)	Local Education Authorities (secondary)	all English LEAs	●secondary school teaching expenditure per pupil ●% children with non-manual head of household ●% children living in houses with all standard amenities ●% ethnicity	●% ≥ 5 higher grade O-level/CSE passes ●% ≥ 6 graded O-level/CSE results ●% ≥ 1 graded results at O-level/CSE	
Jesson *et al.* (1987)	Local Education Authorities (secondary)	all English LEAs	●secondary school teaching expenditure per pupil ●% children with non-manual head of household ●% children not from one-parent families ●% ethnicity	●% ≥ 5 higher grade O-level/CSE passes ●% ≥ 3 graded O-level/CSE results	

Lovell *et al.* (1994)	high schools	sample of 1032 schools throughout USA – data from High School & Beyond	three separate models used to evaluate (a) resources –eg staff numbers, facilities, books - into services - eg number of classes provided in each subject area (b) services into educational outcomes – eg test scores, proportion of pupils proceeding to college (c) services into labour market outcomes – eg postsecondary grades, higherst education attained, subsequent income in the labour market. Results of first stage DEA then form regressand in a statistical analysis designed to explain efficiency differences. Regressors are mainly categorical variables.		
Kirjavainen and Loikkanen (1998)	senior secondary schools	291 of 450 senior secondary schools in Finland	●teaching hours per week ●non-teaching hours per week ●experience of teachers ●education of teachers ●admission level ●educational level of pupils' parents	●number of students passing grade ●number of graduates ●score in compulsory subjects (matriculation exam.) ●score in additional subjects (matriculation exam.)	use Tobit to explain DEA efficiencies; adopt a jackknifing approach to test robustness of DEA results
Mancebon & Mar Molinero (1998)	primary schools	all primary schools in Hampshire, Southampton, Portsmouth	●teacher-pupil ratio ●% not on free school meals	●%successful in SAT2 English ●% successful in SAT2 science	uses OLS to explain the DEA efficiencies
Mayston & Jesson (1988)	Local Education Authorities (secondary)	all English LEAs	●% children from high socio-economic group households ●% children not from one-parent families ●% children with head of household unemployed	●% ≥ 5 higher grades at O-Level/CSE ●% ≥ 6 graded O-level/CSE ●% ≥1 graded O-level/CSE	
Norman & Stoker (1991)	secondary	one (unnamed) English LEA	●running costs ●% children with English as first language ●% children with no referral to counselling ●% children with above average scores in aptitude tests	●exam results ●% pupils entering employment or higher education on leaving	unusual in having an output which is not based on test scores

Ray (1991)	districts operating high schools	Connecticut	●FTE teachers per pupil●FTE support staff per pupil● FTE administrative staff per pupil	district average score of 9^{th} grade in each of: ●maths ●language ●writing ●reading	uses regression to explain DEA efficiencies using environmental varilables as regressors
Smith & Mayston (1987)	Local Education Authorities (secondary)	all English LEAs, with detailed results reported for LEAs in the outer London boroughs	●% children from high socio-economic group households ●% children not from one-parent families ●% children not in poor housing ●teaching expenditure ●non-teaching expenditure	●% ≥ 1 A level pass ●% ≥ 5 higher grades at O-Level/CSE ●%≥ 6 graded O-level/CSE	
Thanassoulis & Dunstan (1994)	lower secondary	schools in one (unnamed) British LEA	●mean verbal reasoning score on entry●% pupils not on free school meals	●mean GCSE score ●% pupils not unemployed after GCSE	Unusual in having an output which is not based on test scores

Table 2 Ranking of schools by technical efficiencies and selected characteristics, 1993 and 1997

	Technical Efficiency score			Outputs in DEA				Inputs in DEA			
School efficiency (1993 rank)	Efficiency 1993	Efficiency 1997	Δ Eff1993 -97	5+A*-C GCSE (%) 1993	5+A*-C GCSE (%) 1997	Attendance rate 1993	Attendance rate 1997	Proportion ineligible for free meals 1993	Proportion ineligible for free meals 1997	Proport'n of qualified staff 1993	Proport'n of qualified staff 1997
				The top 8 schools in 1993							
School1	100.00	100.00	0.00	.27	.29	.969	.970	.148	.201	.957	.947
School2	100.00	96.17	-3.83	.90	.88	1.000	1.000	.980	.959	1.000	.976
School3	100.00	87.59	-12.41	.35	.38	1.000	.995	.200	.566	.990	.959
School4	100.00	84.99	-15.01	.03	.12	.979	.997	.745	.733	.743	.873
School5	100.00	91.89	-8.11	.35	.32	.992	.989	.491	.394	.816	.959
School6	100.00	86.68	-13.32	.07	.16	.977	.959	.098	.354	1.000	.986
School7	100.00	82.56	-17.44	.63	.64	.997	1.000	.962	.939	.865	1.000
School8	100.00	98.56	-1.44	.88	.90	.999	1.000	.974	.969	.954	.951
Median School 1993	83.37	75.21	-8.16	.12	.17	.994	.975	.756	.719	.941	.989
Mean of variables	83.65	79.70	-3.95	.35	.40	.989	.989	.826	.799	.981	.986
				The bottom 8 schools in 1993							
School2650	75.41	73.19	-2.22	.06	.14	.977	.957	.916	.787	1.000	.973
School2651	75.21	76.73	1.52	.19	.33	.945	.990	.762	.755	1.000	1.000
School2652	75.17	85.50	10.33	.22	.22	.889	.987	.529	.432	1.000	.998
School2653	74.79	77.34	2.55	.07	.07	.908	.936	.598	.531	1.000	1.000
School2654	74.63	78.87	4.24	.13	.27	.883	.937	.530	.520	1.000	.995
School2655	74.59	78.82	4.23	.17	.37	.943	.984	.793	.793	1.000	.961
School2656	72.75	89.90	17.15	.08	.06	.785	.999	.301	.338	1.000	1.000
School2657	70.67	83.30	12.63	.06	.08	.822	.933	.486	.355	1.000	1.000

Table 2 (continued)

School efficiency (1993 rank)	School size 1993	School size 1997	Pupil-teacher ratio[1] 1993	Pupil-teacher ratio[1] 1997	Unemploy -ment rate 1993	Unemploy -ment rate 1996	Rivals within 2km Radius[2]
	Selected characteristics of the school and the local environment						
	The top 8 schools in 1993						
School1	833	824	13.830	14.631	.14	.12	7
School2	1022	1087	16.321	16.542	.08	.04	3
School3	1345	1360	14.124	15.314	.14	.12	7
School4	521	506	15.755	15.587	.14	.11	1
School5	584	587	14.065	14.736	.15	.13	6
School6	552	486	13.416	14.375	.10	.08	2
School7	902	930	16.872	17.425	.14	.10	3
School8	1005	1007	16.194	15.991	.09	.06	3
Median School 1993	1037	904	16.140	15.890	.12	.13	0
Mean of variables	862	923	15.707	16.343	.12	.10	1.362
	The bottom 8 schools in 1993						
School2650	486	550	16.918	16.745	.10	.07	0
School2651	500	458	14.966	16.286	.12	.10	0
School2652	906	695	14.465	14.842	.15	.13	5
School2653	497	501	15.102	16.259	.12	.10	3
School2654	887	948	15.212	15.967	.26	.23	6
School2655	851	985	15.283	16.095	.10	.08	0
School2656	600	494	13.936	15.282	.12	.10	2
School2657	434	431	14.690	15.307	.13	.09	4

Notes: 1=Predicted values of the pupil-teacher ratio; 2= Because there are very few school closures and openings over this time period, the number of rival schools is constant over time by construction.

Table 3 The determinants of technical efficiency in secondary schools, 1993-98, tobits (maximum likelihood estimates)

	1993		1994		1995		1996		1997		1998	
	Coefficient (s.e.)	**Prob value**	**Coefficient (s.e.)**	**Prob value**	**Coefficient (s.e.)**	**Prob value**	**Coefficient (s.e.)**	**Prob value**	**Coefficient (s. e.)**	**Prob value**	**Coefficient (s. e.)**	**Prob value**
R1	0.252 (0.118)	0.033	0.725 (0.151)	0.000	0.328 (0.105)	0.002	0.352 (0.094)	0.000	0.626 (0.130)	0.000	0.508 (0.119)	0.000
R12	0.167 (0.062)	0.007	0.245 (0.079)	0.002	0.146 (0.055)	0.008	0.083 (0.049)	0.092	0.298 (0.068)	0.000	0.261 (0.063)	0.000
R23	0.076 (0.052)	0.141	0.160 (0.066)	0.016	0.023 (0.046)	0.624	0.049 (0.041)	0.237	0.162 (0.057)	0.004	0.135 (0.052)	0.010
R35	-0.053 (0.024)	0.024	0.027 (0.030)	0.371	-0.017 (0.021)	0.414	0.007 (0.019)	0.697	0.100 (0.025)	0.000	0.066 (0.023)	0.005
S1	-0.545 (0.310)	0.078	-1.353 (0.396)	0.001	-0.488 (0.273)	0.074	-0.382 (0.243)	0.117	-0.541 (0.337)	0.109	-0.596 (0.311)	0.055
S12	0.077 (0.216)	0.721	0.138 (0.277)	0.620	0.238 (0.192)	0.214	0.127 (0.170)	0.455	-0.183 (0.236)	0.439	-0.306 (0.217)	0.159
S23	-0.293 (0.224)	0.191	-0.341 (0.287)	0.236	-0.055 (0.200)	0.782	-0.164 (0.179)	0.361	-0.430 (0.247)	0.081	-0.450 (0.228)	0.048
S34	-0.173 (0.191)	0.365	-0.621 (0.246)	0.012	-0.271 (0.171)	0.113	0.071 (0.153)	0.645	-0.536 (0.212)	0.011	-0.441 (0.195)	0.024
S45	-0.145 (0.179)	0.415	-0.333 (0.230)	0.148	0.056 (0.160)	0.728	-0.213 (0.142)	0.135	-0.390 (0.196)	0.047	-0.218 (0.181)	0.228
Secondary Modern	-2.102 (0.320)	0.000	-3.094 (0.414)	0.000	-0.787 (0.288)	0.006	-0.775 (0.258)	0.003	-1.865 (0.354)	0.000	-2.126 (0.325)	0.000
Voluntary Controlled	1.167 (0.379)	0.002	1.089 (0.484)	0.024	0.368 (0.335)	0.272	0.104 (0.302)	0.730	0.190 (0.418)	0.650	0.290 (0.385)	0.452
Voluntary Assisted	1.586 (0.217)	0.000	1.727 (0.288)	0.000	1.088 (0.197)	0.000	0.947 (0.178)	0.000	1.447 (0.244)	0.000	1.570 (0.225)	0.000
Special Agreement	1.089 (0.563)	0.053	0.933 (0.730)	0.201	0.891 (0.546)	0.103	1.176 (0.489)	0.016	1.413 (0.676)	0.037	1.329 (0.623)	0.033

Table 3 (continued)

	1993		1994		1995		1996		1997		1998	
	Coefficient (s.e.)	**Prob value**	**Coefficient (s.e.)**	**Prob value**	**Coefficient (s.e.)**	**Prob value**	**Coefficient (s.e.)**	**Prob value**	**Coefficient (s. e.)**	**Prob value**	**Coefficient (s. e.)**	**Prob value**
Grant Maintained	0.789 (0.185)	0.000	0.856 (0.227)	0.000	1.108 (0.157)	0.000	0.808 (0.139)	0.000	0.494 (0.193)	0.011	0.886 (0.178)	0.000
Boys only	0.639 (0.318)	0.045	-0.215 (0.409)	0.599	-0.139 (0.284)	0.625	0.306 (0.256)	0.232	0.299 (0.355)	0.400	0.337 (0.329)	0.306
Girls Only	2.645 (0.295)	0.000	3.842 (0.377)	0.000	2.764 (0.261)	0.000	2.903 (0.234)	0.000	3.998 (0.323)	0.000	4.232 (0.296)	0.000
UnemploymentRate	2.346 (2.027)	0.247	8.216 (2.638)	0.002	2.726 (1.900)	0.151	2.743 (1.730)	0.113	7.706 (2.343)	0.001	6.216 (2.160)	0.004
Population Density	-0.010 (0.006)	0.113	-0.007 (0.008)	0.368	0.006 (0.006)	0.347	0.000 (0.005)	0.988	-0.001 (0.007)	0.840	0.004 (0.006)	0.534
% Professional & Managerial	20.509 (1.327)	0.000	22.495 (1.720)	0.000	13.438 (1.217)	0.000	11.488 (1.109)	0.000	18.557 (1.462)	0.000	16.831 (1.348)	0.000
School size	0.002 (0.000)	0.000	0.002 (0.000)	0.000	0.001 (0.000)	0.000	0.001 (0.000)	0.000	0.001 (0.000)	0.004	0.001 (0.000)	0.000
Expre on teachers pp	0.001 (0.001)	0.041	0.002 (0.001)	0.001	0.002 (0.001)	0.001	0.002 (0.001)	0.000	0.002 (0.001)	0.000	0.002 (0.000)	0.000
Expenditure on Books and materials pp	-0.001 (0.002)	0.747	-0.006 (0.003)	0.012	0.000 (0.002)	0.805	0.002 (0.001)	0.183	0.000 (0.002)	0.936	0.000 (0.002)	0.889
Pupil-teacher Ratio	0.577 (0.089)	0.000	-0.047 (0.113)	0.676	0.068 (0.084)	0.421	0.092 (0.076)	0.224	-0.641 (0.107)	0.000	-0.262 (0.098)	0.008
Constant	65.160 (1.788)	0.000	70.833 (2.210)	0.000	76.623 (1.731)	0.000	75.539 (1.566)	0.000	79.069 (2.015)	0.000	75.292 (1.850)	0.000
Log Likelihood	-6896.74		-7553.47		-6580.50		-6295.15		-7143.66		-6927.08	
χ^2	666.92	0.000	665.97	0.000	531.50	0.000	598.55	0.000	923.33	0.000	969.09	0.000
Pseudo R^2	.046		.042		.039		0.045		0.061		0.065	
N	2657		2657		2657		2657		2657		2657	

Table 4 The determinants of the change in efficiency 1993-98

Variable	Coefficient (s.e.)	Probability value
R1	0.366 (0.103)	0.000
R12	0.189 (0.054)	0.001
R23	0.126 (0.045)	0.006
R35	0.108 (0.020)	0.000
S1	-0.295 (0.272)	0.279
S12	-0.256 (0.190)	0.178
S23	-0.269 (0.197)	0.172
S34	-0.420 (0.168)	0.012
S45	-0.139 (0.157)	0.378
Secondary Modern	-1.429 (0.281)	0.000
VoluntaryControlled	-0.093 (0.335)	0.781
VoluntaryAssisted	0.664 (0.192)	0.001
SpecialAgreement	0.789 (0.492)	0.109
GrantMaintained	0.289 (0.174)	0.098
Boys only	0.231 (0.283)	0.414
Girls only	2.742 (0.263)	0.000
Population density	0.019 (0.005)	0.000
% Professional & Managerial	5.826 (1.108)	0.000
ΔUnemploymentrate, 1993-96	14.131 (5.726)	0.014
Δ Fitted pupil-teacher ratio, 1993-97	-0.474 (0.118)	0.000
Δ School size, 1993-98	0.002 (0.000)	0.000
Δ Expenditure on books and materials, 1993-96	0.002 (0.001)	0.198
Δ Expenditure on teachers, 1993-96	0.001 (0.000)	0.010

Table 4 (Continued)

Variable	Coefficient (s.e.)	Probability value
Efficiency (1993)	-0.511 (0.017)	0.000
Constant	38.741 (1.359)	0.000
R^2	.381	
F(24, 2632)	67.64	0.000
N	2657	

Notes: Standard errors corrected for heteroscedasticity.

Appendix

Table A1 Mean values

Variable	1993	1994	1995	1996	1997	1998
Efficiency	83.655	81.926	86.418	85.484	79.70	81.99
R1	0.305					
R12	1.057					
R23	1.478					
R35	4.362					
S1	0.037					
S12	0.071					
S23	0.066					
S34	0.087					
S45	0.090					
Secondary Modern	0.059	0.057	0.056	0.054	0.057	0.057
Voluntary Controlled	0.030	0.030	0.030	0.029	0.029	0.029
Voluntary Assisted	0.106	0.099	0.100	0.100	0.100	0.100
Special Agreement	0.013	0.013	0.011	0.011	0.011	0.011
Grant Maintained	0.15	0.17	0.17	0.18	0.18	0.18
Boys only	0.045	0.046	0.046	0.045	0.045	0.044
Girls only	0.056	0.056	0.055	0.055	0.055	0.056
Unemployment rate	0.12	0.11	0.10	0.09	0.09	0.09
Population density	17.38					
Prof & Manage (%)	0.24					
School size	861.76	884.51	905.04	911.86	922.62	931.01
Expenditure on teachers	1626.95	1539.54	1624.66	1655.65		
Expenditure on books and materials	97.93	101.92	105.57	101.84		
Pupil-teacher ratio (fitted)	15.71	15.82	15.93	16.23	16.34	

Table A2 Definition of variables

Variable name	Abbreviated name	Definition
Inputs in DEA		
Socio-economic background	INELIG	The proportion of pupils ineligible for free schools meals.
Staff qualifications	QUALST	Qualified staff with formal teaching qualifications excluding student teachers.
Outputs in DEA		
Attendance rate	ATTEND	One minus the proportion of unauthorised absences.
Examination results	EXAM	Five or more GCSE (General Certificate of Secondary Education) grades A* to C.
Dependent variable - tobit		
Technical efficiency	-	Measure of technical efficiency from DEA, 1993-97.
Regressors – tobit		
	TYPE	
County (base)	-	Maintained by the local education authority (LEA) which has an influence on admissions.
Voluntary Controlled	-	Maintained by the LEA. Usually religious foundation. Appoints the governing body.
Voluntary Aided	-	Maintained by the LEA.
Special Agreement	-	
Grant Maintained	-	Financed by central government through the Funding Agency for Schools. Governing body responsible for admissions.
SELECTION POLICY		
Comprehensive (base)	-	Non-selective school.
Secondary Modern	-	Non-selective school, but near to Grammar school.
	RESOURCE	
Expenditure on teachers pp	-	LEA expenditure on teachers per pupil (£000), 1993-97.
Expenditure on books pp	-	LEA expenditure on books per pupil (£000), 1993-97.
Pupil-teacher ratio		The number of pupils in school divided by number of full-time equivalent teaching staff.
School size	-	The number of pupils on the school roll.
	GENDER	
Mixed (base)	-	Co-educational school.
Girls only	-	Girls only school.
Boys only	-	Boys only school.
	ENVIRON	
Unemployment Rate	-	Unemployment rate in the Local Authority District (LAD) 1993-97.
%Professional& Managerial	-	Proportion of adults in professional and managerial occupations in the LAD.
Population Density	-	The population density of the LAD.
	COMP	
Selective schools	S1	Number of selective schools within 1 kilometre radius.
	S12	Number of selective schools between 1 – 2 kilometres radius.
	S23	Number of selective schools between 2 – 3 kilometres radius.
	S34	Number of selective schools between 3 – 4 kilometres radius.
	S45	Number of selective schools between 4 - 5 kilometres radius.
Non-selective schools	R1	Number of non-selective schools within 1 kilometre radius.
	R12	Number of non-selective schools between 1 – 2 kilometres radius.
	R23	Number of non-selective schools between 2 – 3 kilometres radius.
	R35	Number of non-selective schools between 3 – 5 kilometres radius.

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NOTES

[1] Gregg and Machin (1997) show that a poor school attendance record leads to disadvantage in the labour market as an adult.

[2] In the long-run, successful schools may wish to expand their scale of operation subject to LEA approval. (The latter retain primary responsibility for the planning of the supply of school places except in areas where over 80% of places are opted-out (i.e. are Grant Maintained) in which case the role is transferred to the Funding Agency for Schools.)

[3] In the words of the *Parent's Charter*: "Your choice of school directly affects that school's budget - every extra pupil means extra money for the school. So your right to choose will encourage schools to aim for the highest possible standards" (p.14). The grouping of a school, which affects the headteacher's salary, depends upon pupil numbers.

[4] It also suggests that relatively poor exam performance and high truancy are two indicators of a low quality school.

[5] Of course, there may be confounding factors, such as family background. We allow for these in the more rigorous analysis which follows.

[6] Some studies have identified a negative relationship between class size and students' subsequent labour market outcomes (Card and Krueger, 1992).

[7] In any event it begs the question of OLS estimated production (or cost) functions as to how positive (or negative) residuals should be interpreted. The recent use of the appropriate frontier models in the context of cost functions has not hitherto been mirrored in the context of educational production functions, though this is something that we attempt in the present paper.

[8] Excellent introductions to DEA may be found in the books by Silkman (1986) and by Norman and Stoker (1991). Somewhat more advanced treatments are offered by Ganley and Cubbin (1992) and by Färe et al. (1994).

[9] The Warwick DEA package is used to solve the suite of linear programmes.

[10] More recent advances in DEA have involved adaptations of the basic method which allow the analysis of situations in which returns to scale are variable (Banker, 1984), and in which the analysis may specify priorities thus in some way constraining the input or output weights vectors (Thanassoulis and Dyson, 1992).

[11] Banker (1993) attempts to give DEA a statistical foundation, but his approach requires strong assumptions and effectively violates the fundamentally non-parametric spirit of DEA.

[12] It ought to be noted at this stage that a substantial literature exists on multi-level modelling of the secondary education system. Our model includes variables at school and LEA levels, but not at the level of the individual pupil. The absence of the latter is the price which must be paid for adopting the DEA approach. It is true (but inevitable) that our approach may suffer aggregation bias; it is equally true that the more disaggregated approach of multi-level modelling fails to face the challenge of evaluating a multi-input multi-output system.

[13] The bulk of the literature on DEA confirms that parsimonious specifications are, in any event, to be preferred.

[14] The truancy rate data need to be treated with some caution since they might be subject to some manipulation by schools. Data from the Youth Cohort Survey suggest that the overall rate of truancy is higher than suggested by the figures used here.

[15] The proportion of pupils ineligible for free school meals reflects the socio-economic composition of the student body. Many studies have shown that a pupils socio-economic background affects their attainment at primary and secondary school (Feinstein, 1998; Feinstein and Symons, 1997), and so in the absence of a measure of prior attainment, the proportion of pupils ineligible for free school meals will act as a proxy (Thomas and Mortimore, 1994). Note that we also included the proportion of pupils with special educational needs in an earlier specification but this had little effect on the calculated efficiencies.

[16] We computed eastings and northings for each school based on postcode, using the Postzon package. Hence different values for the radii were assumed and a count made of the number of schools falling in the relevant area.

[17] We instrument the pupil-teacher ratio variable since it is endogenous. Good schools attract more pupils and so the pupil-teacher ratio will rise in the short-term if schools are reluctant to hire new teachers (Bradley *et al*, 1999). The instruments for the pupil-teacher ratio include the lagged exam performance of the school, school type and other school level variables.

[18] To check the plausibility of the technical efficiencies obtained from DEA we consulted the OFSTED inspectors reports for the top 8 schools. In each case a high proportion of lessons are deemed to be satisfactory or better, the management of the school is good and the ethos of these schools is one of support and care for the pupils. The implication is that the educational process is efficient in these schools.

[19] This proportion is unusually low. To check the accuracy of the data for this school we obtained an OFSTED Inspection Report (1995) which suggests that 'Recruitment difficulties in the past have resulted in some posts being filled by non-qualified staff and a small number of lessons are taught by non-specialists.' Newly qualified staff have subsequently been recruited (see Table 2). This implies that the proportion of qualified teaching staff for school 4 is accurate.

[20] DEA measures efficiency relative to the best practice observed within each year. Some researchers have conducted dymanic DEA exercises (Lynde and Richmond, 1998). This involves pooling data across years and assessing the extent to which technical efficiency varies both across decision-making units and over time. We report the results of a similar exercise later in the paper.

[21] Schools at the bottom of the league tables may receive, via the formula funding mechanism, extra resources to pay for staff, due to special educational needs of pupils. It is largely for this reason that we instrument for the pupil-teacher ratio.

[22] Of the schools deemed technically efficient in 1993, two have a 100 per cent attendance rate. This raises an issue concerning bias due to measurement errorin the attendance variable. The jackknife results reported later provide us with some reassurance that such bias should not be a cause for concern.

[23] 1997 was chosen as the endpoint because we do not have School Census data for 1998.

[24] Note that because there are so few censored observations the tobit estimates can be interpreted as OLS equivalents.

[25] To check for multicollinearity between the competition and population density variables, we drop the latter. There is no effect on the competition variables.

[26] Note, however, the findings of Hanushek (1976) and others.

[27] A reset test confirms that a linear model represents the correct functional form.

[28] These schools may have increased their efficiency by being more selective with respect to ability and behaviour.