Geography, Resources and Primary School Performance

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Executive Summary

It is an uncontroversial claim that school performance depends on social and economic disadvantage of pupil intake and local community. Surprisingly, the issue has received relatively little attention empirically, especially at primary school level. This paper addresses this in some detail by exploring the role of catchment area resources, local interactions and school level inputs on the achievements of pupils in primary schools in England. Using a panel of primary schools in England, matched to Census and more recent local area data, we find that the probability of success in primary school is strongly related to neighbourhood characteristics. A one-standard deviation increase in indices of intake and neighbourhood wealth increases the probability of pupil success by around ten percentage points. Although the common view that urban schools are poor performers, there is evidence that interaction between neighbouring schools in close proximity improves performance and that the probability of success at a school is related to success in neighbouring schools. Once we allow for other aspects of intake disadvantage it appears that schools in cities perform better. Previous work on the impact of school funding and teaching inputs on performance has been inconclusive, because resources per pupil become dependent on prior school performance. After conditioning on prior performance and neighbourhood characteristics, it seems that more and better basic school resources do lead to improved performance. These effects are small, with an extra qualified teacher for each 100 pupils leading to a 2.6 percentage point improvement in success rates, and an extra ten percent on expenditure per pupil improving performance by only 0.4 percentage points.

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1. Introduction

Primary schooling plays a pivotal role in the generation of human capital and the determination of life chances. That parents recognise and respond to this is in evidence in the premiums paid for homes that are close to good state schools, or the fees for private preparatory and pre-preparatory schooling – around £6500 per year on average in England in 2001. Primary age achievements feature strongly in empirical accounts of the determination of individual attainments and other outcomes[1]. The school effectiveness literature has acknowledged the potential importance of primary schools on achievement in secondary school[2], but the primary phase remains relatively under-researched. A particular feature of primary schools in England is that they serve very localised communities, and many schools can be found within relatively narrow geographical areas, at least in the urban environment. This close link between communities and primary schools, and the close proximity of urban schools, means that their role in mediating community influences to individual attainments may be especially strong. On the one hand, we can expect the distribution of school success to follow closely the distribution neighbourhood disadvantage at the micro-geographic level – even more so than for secondary schools which serve far wider catchment areas. But also, the close proximity of primary schools and non-exclusivity of local catchment areas lends itself well to interactions between schools and between children who are neighbours but attend different schools. These interaction effects, if they exist, may encourage the diffusion of educational technologies and community-based advantages across geographical space. Like neighbourhood externalities in general, these kinds of interaction effects can imply increasing returns to neighbourhood-targeted policy initiatives. At a more abstract level, they hint at externalities that may motivate city formation and social interaction in general.

The main focus of this paper is on estimation of the relationship of location, local interactions and community to primary school performance. Any analysis of these issues would, however, be incomplete without consideration of the role of fundamental school-level 'economic' inputs – teacher/pupil ratios, expenditures – and the importance of these factors relative to 'community' inputs. All of these are central concerns for educational policy, both in terms of the efficacy of extra resources in promoting student achievement, and in terms of

[1] See Sparkes (1999) for a survey, or Feinstein and Symons (1999), Dearden et al. (2002) as examples.
[2] Goldstein and Sammons (1994) attribute up to three times as much of the variation in age-16 exam performance to junior school of origin than to the secondary school attended.

the targeting of these resources across geographical and socio-economic space. The substantial body of related literature, spread across educational research, economics, sociology, developmental psychology, urban geography and other disciplines, is evidence of the weight attached to these issues. In Britain, much of this research has been limited to relatively small-scale case studies, cross-sectional analyses, or has been confined to secondary school achievement as measured by pass rates on national examinations at school leaving age. The availability of primary performance tables since the mid 1990s, based on tests[3] in the national curriculum in England, combined with a wealth of school-level information from DfES, now provides a basis for investigation of primary schools at the national scale. By linking this data, through postcodes and national grid references, to Census data from 1991 and to more recent property price, incomes and unemployment data, we can obtain accurate measures of the characteristics of the neighbourhoods in which schools are located. The proximity-based rules by which admissions are usually prioritised ensure that community characteristics are good proxies for characteristics of children at the schools, and of the schools' geographical and community context.

Estimation of the causal influence of school resource inputs is notoriously difficult. On the one hand, educational policy that allocates more resources to failing schools or disadvantaged pupils can lead to inference of negative input-output relationships. On the other hand, we might falsely infer positive effects, or measure upward biased positive effects for a number of reasons. There may be more, better quality teachers in high-performing schools if recruitment and retention is easier. More able or advantaged children might find their way into schools with more or better teachers due to the exercise of parental preferences over class size and teacher quality. If school inputs are linked to local taxation and property prices then pupils with more home-based resources will find themselves in better-resourced schools. Instrumental variables or control function approaches to overcoming these sources of estimation bias are unlikely to succeed, since there are virtually no plausible instruments. Instead, the approach adopted here is to assume that any policy or selection decision is based on persistent, unobserved school characteristics originating prior to the sample, so that fixed-effects estimation, or estimation conditional on prior performance is appropriate.

This paper steps back from investigation of the influence of the specifics of the school environment on individual attainment, and instead uses school level data to assess the

[3] Five years are available from 1996 to 2000, but the accounting rules were changed in 2000, meaning that the results after 1999 are not necessarily consistent with earlier years - see DfEE performance tables 2000

impact of school location on average attainment. What do not do here is address the detail of factors in school effectiveness or the differential impact of these factors on pupils with different needs. These issues have preoccupied school effectiveness research, where the focus is often on potential (rather than average) achievements and on the heterogeneous impact of organizational, leadership and instructional structures. Our school level data precludes such investigation. In any case, individual level data offers no advantages unless explanatory variables are child-specific – personal learning time, and own class size for example – and this introduces a whole new level of endogeneity bias which needs to be overcome.

2. A Summary of Related Work

The debate over the relative importance of school inputs and the socio-economic background of pupils and the community context of the school has remained largely unresolved since the findings of the Coleman report (Coleman *et al.*, 1966) that school composition mattered far more than school resource inputs. These findings motivated over three-decades of school effectiveness research, which has, in the UK at least, focussed largely on the secondary phase. Even then, evidence on the impact of neighbourhoods and intake characteristics – beyond the impact of pupil free school meal entitlement – is limited. To the author's knowledge, no study in the UK has looked in detail at the relationship between neighbourhood characteristics and primary school performance.

Even the basic relationship between teaching inputs and pupil attainments is relatively unexplored in the primary phase, although the literature on secondary school resources and outcomes, and on secondary school effectiveness and improvement is vast – see, for example, Burtless (1996) for the US, and White and Barber (1997) and Vignoles *et al.*, (2000) for UK surveys. Key recent works on the effect of school resources on secondary exam results in the UK, using national, pupil level data, are all based on the National Child Development Survey (Dustmann *et al*., 1998; Dearden *et al*., 2001; Feinstein and Symons, 1999; and Dolton and Vignoles, 1999). Pupil teacher ratios have insignificant effects in most of these studies, and expenditure per pupil (at LEA level) is insignificant in those studies that include it. A recent database of national pupil A/AS-level results provides evidence of differences between institution types in overall attainment at upper-secondary level and in value-added performance (relative to GCSE attainment) Yang and Woodhouse (2001), but specific resource inputs are not tested. The authors find that, at most, 22% of the variance in A-level scores is attributable to establishments.

Only a few studies address the issue of community context empirically, even at secondary level. MacCallum and Redhead (1999) map 1991 census data to residential addresses of just under 2000 pupils in 12 High Schools in the London Borough of Ealing in 1998. In their report summary, the authors report only simple correlation coefficients with no multivariate analysis. The proportion of higher-educated residents in the residential enumeration district has the strongest correlation (0.215, *p*-value<0.0001) with individual Key Stage 3 attainments, and the proportion of ethnic minorities is most strongly associated with GCSE point score. Unsurprisingly, the correlation coefficients are much larger using school level aggregates (since the variance of unobserved determinants of attainments is reduced), up to 0.944 for the association of higher-educated neighbourhoods with Key Stage 3 maths scores for white pupils.

Lupton (2001) finds that 69% of the secondary schools placed in OFSTED's lowest quality Special Measures category were in the top-ten percent of deprived wards ranked according to the DETR 2001 Index of Multiple Deprivation. Only 11% are in the least disadvantaged 40% of wards. Bradley and Taylor (1998) report large and highly significant negative effects from school-level free-school meal entitlement, but surprisingly weak effects from ethnic minorities and pupils with special educational needs on secondary GCSE performance. Using a Data Envelopment Analysis approach, Bradley, *et al*. (1999) find that more *efficient* secondary schools in terms of exam performance and attendance rates are in local authority districts with high proportions of professional and managerial residents, although also in areas with high unemployment rates. Close proximity to other non-selective schools also increases efficiency, a feature that the authors attribute to competitive effects of the quasi-market in secondary education, although they do not consider other potential forms of spatial interaction.

Using census data and 1994 GCSE pass rates aggregated to Local Education level, Gordon (1996) argues that the proportion of non-employed lone parents is the most significant factor in generating spatial disparities in overall and higher-level (Grade A-C) pass rates, and that this is mediated entirely via unauthorised absence rates. Significant factors in higher-grade success rates, conditional on unauthorised absences, are the LEA proportion of non-manual workers (positive), unskilled (negative), non-earners (negative), ethnic group (positive for Indian, negative for Afro-Caribbean) and residential overcrowding (negative).

Variations in the average achievements of pupils by ethnic groups are important in overall inter-LEA performance inequalities. Nevertheless, each of the six ethnic groups studied in Gillborn and Mirza (2000) is the highest attaining group in at least one LEA, and the relative success by ethnic group has changed over the 1990s, and varies with phase of education. Indian pupils have overtaken white pupils in GCSE results since 1991, but the position of Black pupils has not improved and Black pupil attainments appear to decline relative to the mean with each stage of assessment during compulsory schooling. The same report highlights the persistent differences between social classes, within ethnic groups, but also distinct ethnic disadvantage within social class category for Blacks, Pakistani and Bangladeshi pupils.

Most reports on the influence of area disadvantage on school performance highlight the relationship of results to free school meal entitlement or receipt (for example OFSTED, 2000), since this is collected at school level in administrative data. The downward trend in performance as the proportion of the school intake on free-school meals increases is a striking empirical regularity at primary and secondary level. Although this result is unsurprising, the mechanisms that drive it are not well understood, and some schools perform better than others even with similarly disadvantage intakes. However, no single organisational recipe guarantees success (OFSTED, 2000; Lupton, 2001).

In one of the few studies directed specifically at primary schools, Mancebon and Molineri (2000) estimate Key Stage 2 production efficiency using Data Envelopment Analysis on a sample of 176 primary schools in Hampshire, Southampton and Portsmouth. Only free-school meal entitlement appears as an input, and English and Science results as outputs (they reject other inputs in their model selection procedure – including special needs, pupil teacher ratios, gender mix and expenditure per pupil). Average efficiency was 78.5% of what could be achieved with similar intake disadvantage, falling to 41.7% at the bottom end. Regression of the logits of the efficiency scores on a number of other explanatory variables indicates that Church of England schools are substantially more efficient than others, and that parental interest has a role to play – schools for which more parents responded to OFSTED surveys do better, as do those schools of which parents expressed a favourable opinion. The case for an effect of parental opinion on school efficiency, rather than vice-versa, is not made clear.

3. The Primary School Production Function

The base-line strategy in this paper is to estimate an aggregate school-level production function that describes the probability of a pupil, drawn at random from the school, reaching the target grade in final year tests. We assume that this depends on teaching inputs to the school, local geographical interaction effects, on the characteristics of the pupil, on his or her family background and on unobserved school effects. Individual pupil characteristics are unobserved at school level, as are family background characteristics. But, using geographical data on neighbourhood composition, and information on the spatial location of the school, we can estimate the probability that a child's household will have characteristics x_i^h. The general empirical representation of the primary school production function is:

$$p_{s,t} = a_t + \overline{p}_{j,t} b + \mathbf{x}'_{s,t} g + u_{s,t} + hf_j + e_{s,t} \qquad (1)$$

where $p_{s,t}$ is a measure of success rates in school s, a_t is a general time effect, $\overline{p}_{j,t}$ is the average measure of success in the nearest J schools in area j at time t. The term $u_{s,t}$ captures persistent unobserved school-specific factors, such as teaching quality, and we assume this follows an AR(1) process:

$$u_{s,t} = ru_{s,t-1} + v_{s,t} \qquad (2)$$

We incorporate unchanging neighbourhood and catchment area influences by f_j, an unobserved local area effect. The term $e_{s,t}$ is a random school-year-specific disturbance – a cohort effect perhaps, or just noise – and this does not persist over time. The vector $\mathbf{x_{s,t}}$ incorporates our observations or estimates of the expected characteristics of a child at the school at time t, and his or her family background. Parameter b captures local interaction effects, g is a vector of parameters measuring the impact of school-specific inputs and the family characteristics of pupils, r parameterises the persistence of performance over time, conditional on other observed characteristics and h the degree to which neighbouring schools share the same area effects. Setting $p_{s,t} = \Phi^{-1}(p_{s,t})$, where $p_{s,t}$ is the proportion of pupils achieving the target grade, means that the production function can be estimated as a grouped probit[4].

The serially correlated components of the composite error term in (1) means that least squares estimates are inconsistent if the regressors are correlated with past school performance. Neighbouring school performance may be correlated with the composite error term in a number of ways, Firstly, school-to-school feedback mechanisms imply that anything unobserved in the determination of school performance $p_{s,t}$ will also influence neighbours performance $\bar{p}_{j,t}$. More importantly, estimates of b will pick up the effects of unobserved components of neighbourhood composition, which are, in part, shared by school *s* and its nearest neighbours. Regardless of the source of endogeneity, instruments for $\bar{p}_{j,t}$ are available, in that $\bar{\mathbf{x}}_j$, the mean of the *characteristics* of the school's nearest neighbours, is correlated with $\bar{p}_{j,t}$ but not with f_s, nor with other unobservables (conditional on the characteristics of school *s*).

This identification of structural dependence of school performance on neighbouring school performance – *endogenous* neighbourhood effects, to use the terminology of (Manski, 1993) – rests on the assumption that there are no *exogenous* neighbourhood effects so school performance is not affected by the observed determinants of school performance in neighbouring schools. The distinction is not so important in the current application since we wish only to identify the interdependence of schools, as distinct from their mutual dependence on outside influences. To make this clearer, we do not necessarily wish to rule out the impact on school performance of teaching techniques in a neighbouring school, whether or not this spillover is mediated via test pass rates in the neighbouring school.

Serious problems arise once we try to get consistent estimates of the parameters on most types of school and neighbourhood inputs, for which there are no plausible instruments. Local government targeting of resources on the basis of needs, and parental choice of school and residential location, means that many of the factors that we expect to influence school performance are determined by prior performance, and hence correlated with the term $u_{s,t-1}$. Classes may be smaller in poor performing schools that have low demand for places, or schools in difficulty may receive more teachers and resources. Resources are allocated to

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[4] By weighted least squares using weights $\left\{n_s f\left(\Phi^{-1}(p_{st})\right)^2 / p_{st}(1-p_{st})\right\}^{0.5}$

Local Education Authorities according to educational needs, and a similar redistribution occurs to some extent within LEAs. Property prices and incomes will be higher close to schools which perform well due to parental competition for places (see Gibbons and Machin, 2001). We can, however, apply a Cochrane-Orcutt transformation to the model to remove the serially correlated error term, and estimate the model conditional on prior performance. Because the performance of pupils taking tests in year t is not specifically related to school characteristics in year *t*, we treat most school inputs and any time varying local characteristics as fixed in the short run at $\mathbf{x_s}$, measured by the average over the sample periods. The assumption here is that $\mathbf{x_s}$ is determined by a pre-sample value of u_s. Our model is now:

$$p_{s,t} = rp_{s,t-1} + a_t - r\,a_{t-1} + \overline{p}_j ßs + \mathbf{x}'_s gs + f_s s + e_{s,t} - re_{s,t-1} \qquad (3)$$

in which $s = (1 - r)$. The presence of the lagged disturbance term and the inclusion of the lagged performance term as a regressor imply that OLS estimation of (3) will be biased. IV estimation using $p_{s,t-2}$ as an instrument for $p_{s,t-1}$ gives consistent estimates.

3.1 Family background or neighbourhood interaction effects

A non-zero b in model (3) indicates area-based interaction effects between schools, between pupils or parents of children at different schools in close proximity. The kinds of interaction we have in mind are educational technology spillovers between schools, or learning process-based peer group effects amongst pupils associated with schools in close proximity. The mix of social and non-socially housed tenants in most primary schools suggests an alternative way of getting at community or neighbourhood effects in primary school performance. Owner occupier and private tenants' demand for property and local amenities means that property prices and the physical characteristics of owner-occupied or private rented property are determinants of the mean local incomes of owner-occupiers and private tenants – and hence education and other related family resources of these groups. These factors do not, however, influence local social tenant incomes or resources, whose allocation to homes is unrelated to the process which sorts private market tenancy groups into high and low income neighbourhoods. Essentially, property prices are a proxy for wealth and other resources in the home-owner community, so relate directly to the probability that the child of a home-owner attains target grades in primary school age tests. But property prices have *no* direct bearing on the incomes or other family resources of social tenants.

We can write the probability of a child reaching target achievement in primary school as:

$$p_s = p^c + \left(p^o - p^c\right)\cdot q_s^o + w_s \qquad (4)$$

where p^o (p^c) is the probability that a non-social tenant child (social tenant child) reaches the target grade, and q_s^o is the proportion of non-social tenants in school s. If we assume that the deviation of the expected attainment of a non-socially housed child from that of a social tenant's child is linearly related to local property prices (or a transformation of these) z_s then (4) becomes

$$p_s = p^c + \left(l_1 + l_2 z_s + n_s\right)\cdot q_s^o + w_s \qquad (5)$$

If z_s is exogenous, then (5) may be estimated by weighted-least-squares (allowing for the heteroscedastic error term). A test for general effects from z_s, not specific to home-owners or private tenants, is to estimate

$$p_s = p^c + l_0 z_s + l_1 q_s^o + l_2 z_s q_s^o + \mathbf{x_s} b + \tilde{w}_s \cdot \qquad (6)$$

and test for $l_0 = 0$. Semiparametric estimation of the regression surface of school performance on q_s^o and z_s, conditional on $\mathbf{x_s}$, can also provide insights because we can observe the response of school performance to z_s at different points in the within-sample distribution of q_s^o.

There are some obvious objections. Firstly, all interaction-based neighbourhood effects could operate through peer groups in the school itself. In such a case, there will be *no* general effects which are uncorrelated with the proportion of non-social tenancy children in the school, since q_s^o equal to zero means that the mediating peer group is non-existent. Secondly, social tenants who are more motivated towards their child's upbringing may self-select into accommodation in neighbourhoods with higher property prices or larger owner occupier properties, though this is unlikely given the restricted availability of council housing. Lastly, the incomes and other resources of neighbouring social tenants may be objects of preference in owner occupiers' and private tenants' housing demands, leading to correlation between property prices (and hence owner-occupier incomes) and social tenant resources, even conditional on the proportion of social tenants[5]. We can test this last assumption using data on incomes of social and non-social tenants living in close proximity. It is also worth noting that selection by owner-occupiers on school performance itself cannot be factor driving a price-performance relationship at the zero owner-occupier school admission rates which correspond to the main effect of property prices l_0.

4. The Data, and Matching Methods

Our core dataset, provided by the Department of Education and Skills, contains basic school characteristics and performance based on age-11 Key Stage 2 assessment tests. These tests are common to all schools, and assess progress through the National Curriculum. Age-11 pupils are expected to reach Level 4 in these tests, and the performance figures give the proportion in each school reaching this grade. Importantly for the spatial emphasis in the current work, the data set includes location identifiers – the region, parliamentary constituency, postcode and National Grid Reference of the school premises. Our central aim is to match available local area data to these school locations, and to infer the relationships between performance of nearby schools, and between school performance and local area characteristics. Our local area data comes from a number of sources. Firstly, the 1991 Census provides detailed information at a highly disaggregated level (down to a few hundred households in each Enumeration District). A commercial data set of postcode sector mean incomes for 1996 and 1999 provides more up-to date, but more aggregated, income measurements and household numbers[6]. A postcode sector typically contains 2500-3000 households. At the same level of aggregation, we have annual mean property prices from the Government Land Registry from 1995 on, plus measures of unemployment benefit claimants per household derived from NOMIS postcode sector claimant counts for each year.

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[5] Property prices are certainly influenced by the proportion in social housing, though the issue here is whether property prices are correlated with social tenant resources, conditional on the proportion in social housing.
[6] More recent age data at postcode sector level imputed by another marketing company, Experian, was found to offer no advantages over the Census equivalent. The correlation between the Experian and Census data near unity.

Key Stage Two assessment tests are taken in the spring, in what is normally a child's final year at primary school – generally at age 10-11. Children taking the tests in 1996 would have been aged 5-6 on the night of the Census in 1991. Children taking the tests in 1999 will have been 2-3 years old. Given this, the data from the Census in 1991 should be interpreted as characterising the neighbourhood community around the time of the children's entry into school. As central-tendency measures of the community in which pupils ordinate, this will be noisy to the extent that: 1) the characteristics of the school intake differ from those of the residents in the immediate vicinity, or 2) the classes sitting the tests from 1996 to 1999 are composed of children who have moved in to the area, and exclude those who have moved out, since the Census. Census-based area measures do, however, have a distinct advantage over information on school-year-level economic and social characteristics in that they are more plausibly pre-determined. School composition will change in response to parental selection on performance in previous years. Community composition in 1991 is sensitive only to school performance prior to 1991, and then only to the extent that movements in families with pre-school age children changes the mean composition of the neighbourhood.

To maximise the precision in measurement of the school's catchment area characteristics, we apply a K-nearest neighbour approach to matching the Census data, property prices and local incomes to schools locations. In practice this involves assembling all the community data as means or proportions at Census enumeration district level. We then estimate a school centred, school-age cohort weighted average of the data in the nearest K neighbourhoods around each school, at a set of locations defined by a matrix of school postcode, 10 metre grid references. To refine the data matching still further, we adapt K according to the number of children in the school year, and a first-pass estimation of the number of school-entry-age children in the nearest K_0 enumeration districts, where K_0 is a guess at the typical number of enumeration districts comprising a school catchment area. By way of illustration, Figure 1 shows the catchment area that we would obtain by matching eight enumeration districts to one school in Hackney in East London. The circle is drawn to capture the nearest nine Enumeration Districts, and has a diameter of approximately 800 metres. Details of the method are presented in Appendix A.

Our dataset thus has two distinct levels at which we measure intake and community characteristics. Most are derived in this way from the census and other spatial datasets, and measure community characteristics in the imputed catchment area. We also have limited intake characteristics at school level – proportions of pupils entitled to free school meals, proportions with special educational needs and with statements of special needs and proportions of non-white ethnic groups, plus school type and age range. The strong, graphical relationship between free-school meals entitlement and school performance at both primary and secondary levels is well known – see for example OFSTED (2000). Free-school meal entitlement is often used as a benchmark for comparison of schools that differ in terms of their intake disadvantage.

5. Empirical Results

5.1 Clustering and the geographical distribution of primary performance

We start with a visual assessment of the distribution of primary school performance in England. The geographical distribution and spatial association of performance in primary schools give direct clues to the spatial processes underlying attainments. If schools are more often than not located near other schools with similar pupil achievements, then we might suspect a role for geographical factors – institutional differences between areas, differences in school intake, or endogenous effects based on interactions between local schools. Looking at some maps also reveals some interesting features about city versus rural school performance. Figure 2 illustrates the geographical spread across England at County level in 1999. Counties correspond to Local Education Authorities in most non-metropolitan areas. Panel a) shows the quintiles of county mean Key Stage 2 performance scores (weighted by the number of pupils tested). The quintiles of national 1999 county level mean performance are:

1st:0.631-0.716 2nd:0.717-0.734 3rd:0.734-0.748 4th:0.748-0.767 5th:0.767-0.820

The top fifth of counties are concentrated in the south east and east of England – Surrey, Berkshire, Hertfordshire, Hampshire and Cambridgeshire – in Yorkshire in the north-east, and Cheshire and Merseyside in the north west. The worst counties in the south-east form an arc around the Thames estuary: Greater London, Essex, and Kent. The West Midlands conurbation and several counties in northern-central England are also in the bottom one-fifth. These differences could reflect any number of underlying factors. A prime suspect must be the disadvantage of the school intake. Indeed, once we adjust the scores for the proportion eligible for free-school meals[7], we see a quite different pattern. Predominantly urban counties increase their ranking: Greater London and Tyne and Wear are now in the top quintile. The most notable feature is that schools in a swathe across middle England that were in the top half of the ranking, fall to the bottom once we allow for the fact that more pupils there are from higher-income backgrounds. What is striking here, particularly in the case of London, is that an urban environment is *not* in itself a necessary condition for poor average school performance at the county level. Unsurprisingly perhaps, a high proportion of low-income pupils can be a sufficient condition. We should also note that rural areas can perform well, given local economic disadvantages: the Isle of Wight, Cumbria and Cornwall are all in the top ranking of adjusted scores.

Counties present too broad a level of aggregation to tell us much about spatial clustering of performance, and mask deep local inequalities in performance. Figure 3 presents a more disaggregated picture, with quintiles of performance aggregated to Parliamentary Constituency level[8]. The picture using raw data in panel a) is of good performance in the higher land area semi-rural Constituencies, spreading north from the south coast and running up the middle to west of England. As in Figure 2, we see high-performing regions spreading right across the north. The urban constituencies – particularly in Greater London, the West Midlands – and in pockets in the southern Pennines, perform poorly in the unadjusted data. The effect of adjusting for school intake incomes is startling: in panel b) the broad mass of high performing Constituencies that we saw in central England becomes a central swathe of poor performance, and the schools that are effective despite the income disadvantages of their intake turn out to be clustered in and around Greater London, around Birmingham in the centre, Newcastle, Durham and Middlesborough in the north east, in the north western Manchester-Merseyside conurbation and its hinterland, and in the central and southern urban areas of the Pennines. Schools in cities do *better,* once we adjust for income disadvantage. This, of course, says nothing about which city characteristics are performance enhancing – this is analysed further in Section 5.4.

Visual examination of the spatial clustering of performance at school level on a national scale is infeasible. Instead we turn to statistical evidence based on summary

[7] By taking the residuals from a regression of Key Stage 2 scores on a polynomial in the proportion eligible for free school meals.

[8] Although this has no natural correspondence with schooling, it is the only area classification for which it is straightforward to aggregate school performance and draw map boundaries.

measures of spatial association. The measure chosen is the rank-adjacency statistic. In the current application, this is defined as:

$$D = \frac{\sum_{r=1}^{n}\sum_{s=1}^{n} w_{rs}\left|y_r - y_s\right|}{\sum_{r}^{n}\sum_{s}^{n} w_{rs}}$$

where $w_{ij} = I\{d_{ij} < d_{ik} ; \vee k, j \neq i\}$ and $I\{\ \}$ is the indicator function and y_r is the rank of school r in terms of mean Key Stage 2 pass rates between 1996 and 1999.

So, the statistic is based on the sum of the rank differences between each school and its closest associate in geographical space. The greater the similarity between the ranks of schools in close proximity, the lower the statistic, indicating correlation between scores in neighbouring schools. Table 1 presents rank-adjacency statistics for mean 1996-1999 Key Stage 2 scores, calculated separately for each Government Office Region. Significance tests are base on the normal approximation (Ekawaru and Walter, 2001; Walter, 1994). Statistics with z-scores below –1.64 are significant at the 5% level in this one-sided test. Although the table presents results for weights which link nearest school-pairs, the results were broadly similar under different weighting schemes (*e.g.* inverse distance squared, nearest ten schools). The summary statistics show more spatial association of performance within regions than we would expect if the distribution were random. This is hardly a surprising result if we believe that the background of the pupils drives performance in schools, since the spatial distribution will reflect the underlying distribution of parental resources. Spatial correlation can also arise from differences across space in resource inputs, LEA policy, staff quality and other institutional factors that affect pupil success. The lower panels of Table 1 tests for the importance of these factors by regression adjusting the performance ranks to take out differences between a) local education authority areas b) pupil-teacher ratios, school size, school type (Voluntary, Foundation or Community), average class size and age-range c) the proportion eligible for free-school meals. Although adjusting for free-school meal entitlement or Local Education Authority differences generally reduces the z-scores[9], we reject the null of no spatial clustering of performance in all cases.

[9] This is in part due to the use of the estimated regression residual.

5.2 Sensitivity to catchment area conditions

Figure 2 and Figure 3 illustrate the importance of low-income on the geographical distribution of pupil attainment. We examine this link further, with some fairly descriptive regressions summarising how the income-performance relationship is distributed over time and geographical space. We restrict our attention to local incomes and unemployment, for which we have some time-series variation.

To motivate the analysis, Figure 4 illustrates the performance-income relationship, conditional on Local Education Authority, special needs, school type (community, voluntary aided, foundation or voluntary controlled), age-range and rural-urban location. This regression line is estimated by semi-parametric regression to calculate linear coefficients on the control variables (see for example Robinson, 1988), followed by kernel regression of the residuals on incomes. Performance rises rapidly as local incomes increase at the bottom and centre of the distribution, but there are obvious diminishing returns to local incomes. The lower panel illustrates the relationship between unemployed claimants per household and performance in subsequent years, unconditional on incomes. A glance at Figure 6 in Appendix B suggests that these relationships are not primarily generated by selection of parent types on school characteristics: performance increases monotonically with property size, which is exogenous (at least in the short run).

Table 2 separates out and parameterises the contributions of income and unemployment. As before, additional controls are school type and age indicators, special needs measures, urban-rural and local education authority dummy variables. In reading this table, we should interpret income and unemployment as indices of local conditions, since we have done nothing here to separate the effects of these characteristics from other aspects of family background, other than special needs and ethnicity.

Performance increases with catchment area incomes in all regions, and the slope of the relationship at the mean is similar in all regions. Looking at 1996, we could restrict the slope to be equal across regions at 0.428 and would not reject equality at the 5% level (p-value = 0.654). A 1% relative increase in incomes is linked to a 0.43 percentage point increase in primary school achievement. Taken individually, none of the slopes is significantly different from the minimum distance estimate (p-value $\geq$ 0.121). As we move across the table from 1996 to 1999, the income effect diminishes. This is a corollary of the mean improvement in Key Stage 2 achievement rates in all regions, since the improvement is a result of catch-up by schools at the bottom of the distribution of performance in 1996 (this is documented in Gibbons and Machin, 2001). Again, the slope in 1999 is equal across regions at 0.261 (*p*-value = 0.198). This pattern of results shows considerable success, on average, in efforts to improve the performance of poor-performing schools in low-income neighbourhoods in the late 1990s.

There is a lot more variation in the sensitivity to increases in catchment area unemployment rates. As we might have expected from Figure 5, the relationship is uniformly negative in 1996, but the decrease in performance associated with unemployed claimants varies considerably over regions in any one year. As we move across any row in the table, the association becomes generally weaker in all regions except the North East and North West, as unemployment claimant rates fell in all regions. The coefficients on unemployment in 1999 are not statistically significant, except in these northern regions, by 1999. This pattern presumably reflects changes in the composition or duration structure of unemployment between 1996 and 1999, and differences between the North and the rest of England. This instability indicates that the structural effect of unemployment is probably quite weak. What is clear is that the relationship observed in the lower panel of Figure 4 is largely attributable to household incomes, or income-related heterogeneity other than unemployment.

This all suggests that we can reasonably restrict our attention to a common effect of catchment area incomes on school performance across regions. The underlying distribution of incomes across the country influences the distribution of school performance, but the returns to income in terms of performance do not vary across geographical space. A stylised fact for the whole of England in 1999 is that pupils in neighbourhoods with a ten percent income advantage were 2.5 percentage points more likely to achieve target grades at Key Stage 2.

5.3 Indices of latent neighbourhood status

It is useful to restrict attention to indices of neighbourhood conditions, rather than the full vector of components. Characteristics of residents in school catchment areas tend to be highly mutually correlated, especially within local areas, since much of the variation is determined by sorting of agent types across space according to the amenities and residential characteristics of the neighbourhoods. For example, the correlation between property prices and incomes is 0.87, and between incomes and unemployment is 0.65. Exogenous variation – due, for example, to labour demand shocks across space – is not a major factor in generating variation within local authorities in neighbourhood unemployment rates or incomes. Income constraints in the demand for neighbourhood quality, plus the location of social housing are much stronger influences on the spatial distribution of characteristics.

It then makes sense to collapse these variables into a smaller number of indices of neighbourhood status by some dimensionality reduction technique. This is done here using the principal factor method (see Bartholomew and Knott, 1999). In practice, one factor (latent variable) dominates the covariance structure of the neighbourhood variables, and only this factor is retained. A theoretical justification of this procedure is that there exists an unobserved, scalar latent neighbourhood 'quality' variable that we can recover by factor analysis of the characteristics of residents. This 'quality' variable may simply reflect neighbourhood wealth, but since neighbourhood wealth will follow the distribution of neighbourhood quality (if residents are optimising and this neighbourhood quality is a normal good) we cannot identify its precise nature. In what follows, we shall refer simply to *neighbourhood status*. The advantage of this reduction in the data is that it offers us a simplified, broad-brush picture of how neighbourhood relates to pupil achievement.

Table 3 repeats the cross-regional analysis using this index of neighbourhood status derived by factor analysis of incomes, property prices, unemployment rates and the proportion at the school who are eligible for free school meals[10]. These are the only time varying measures of intake and catchment area conditions available, except for the special educational needs and ethnic indicators. These last factors are retained as controls in the regression to allow for linguistic and learning disadvantages of school pupils, which are not necessarily due to economic disadvantages. The table reports the effect of a one-standard deviation increase in the index.

The pattern is similar to that in Table 2, with declining sensitivity to catchment area status in most regions from 1996 to 1999. Only in London is there no obvious change over time (the marginal effects are equal across periods, p-value = 0.987), though the coefficients are not significantly different in the statistical sense for the East or West Midlands (p-values 0.154 and 0.583 respectively). Any differences between regions in the relationship between intake disadvantage and performance are relatively small, although they are significant in 1997 and 1999. Schools in neighbourhoods that were one-standard deviation above the

[10] In practice, there is no ambiguity in the choice of factors for the index. Only the first factor in this analysis has factor loadings that correspond to the intuition that incomes and property prices increase economic status, whilst unemployment rates and free-school meal eligibility decrease it. Between 85%-90% of the information

average neighbourhood could expect a 12.5 percentage point advantage in 1996, falling to around 9.5 percentage points in 1999. This average relationship is pretty much in line with what we see by visual inspection of Figure 4, with a ten percentage point change for a shift from mean incomes (£19500 in 1996) to one standard deviation above (£23900).

5.4 Disentangling the contributions of local characteristics

So far we have looked at the impact of local incomes and unemployment on school performance, and the relationship to a time-varying index of intake and local conditions across regions. We now dispense with concerns about regional differences, test for the importance of selection effects on the observed catchment area-performance relationship, than look at the idiosyncratic contributions of neighbourhood characteristics. Table 4 shows estimates of the influence of neighbourhood characteristics using pooled data for 1998 and 1999 for all regions. Again, we will start with a characterisation of the neighbourhood-performance relationship using a quadratic in a single factor derived by factor analysis of a number of catchment area characteristics and free-school meal entitlement. Special educational needs and ethnicity are retained as controls, along with school type, age range, rural-urban, year and LEA dummies. Column 1 of Table 4 excludes free-school meal entitlement from the catchment area index, whilst Column 2 includes it[11]. All neighbourhood characteristics are potentially endogenous in a school production function. This issue is highlighted by the results in Gibbons and Machin (2001) that show substantial property price *premia* close to schools with exogenously better performance. Columns 3 and 4 repeat the analysis, but with instrumented lagged school performance as a control for persistent components of school performance, which might induce residential selection and inconsistent estimates.

The impression from this table is, perhaps unsurprisingly, of school performance increasing with catchment area status and decreasing with school intake income disadvantage. The effects of catchment area conditional on school intake are quite small, though increasing with neighbourhood status. A one-standard deviation increase from the mean increases performance by nearly four percentage points; another one-standard deviation increases it by a further five percentage points. Obviously if we were to remove the intake

contained in incomes, unemployment and property prices at the neighbourhood level, plus free school meal eligibility can be captured in this single linear combination.

[11] Details of the factor analysis are in Appendix D.

characteristics from the regression, this would rise. Instead, what we do in Column 2 is include free-school meal entitlement in the neighbourhood status index, and retain special needs and ethnic group as controls. Here we find that a one standard deviation neighbourhood improvement from the mean increases performance by just over ten percentage points, rising to thirteen percentage points for a further standard deviation shift[12]. This is much like the result we saw in the cross-regional analysis in Table 3, suggesting that all the additional neighbourhood variables add very little information in terms catchment area effects on performance.

Turning to the models in Columns 3 and 4 that control for persistent unobserved school components, we find little change in the estimated parameters. The Hauseman tests of parameter equivalence do not reject the exogeneity of neighbourhood composition, as measured by this composite index[13].

So far we have looked at the relationship between school performance and a neighbourhood index. Table 5 separates out the impact of the components of neighbourhood status. All these covariates are moderately to highly correlated and are measured with an unknown degree of error, so we should take care before placing too strong a causal interpretation on their separate contribution. Column 1 is straightforward grouped probit on the battery of catchment area characteristics. Column 2 conditions on the intake characteristics available at school level. Columns 4-6 repeat this sequence but are IV estimates with lagged performance.

Most of the neighbourhood attributes have the signs we would expect if we interpret them as measures of household economic resources. With the Census-derived neighbourhood attributes in the regression, the impact of local incomes is reduced to around one-third of what we estimated in Table 2. The regressions show no statistically significant effects from local incomes, property values or unemployment rates in the transformed model with lagged performance. The only highly significant (at least at the 5% level) catchment area characteristics in Column 3 are the proportion highly qualified, average age, owner-occupier property size, the proportion of non-socially housed children and long-term sick rates. The latter impact of the last two characteristics is absorbed by the proportion eligible for free school meals or with special educational needs in Column 4. The only catchment

[12] Without the special needs controls, the effect of a one standard deviation increase in catchment area status rises to just under 14%.

area characteristic that is significant at the 1% level is the education of local residents. It is fairly clear from these results that the major neighbourhood determinants of pupils' failure to reach target attainments (aside from special educational needs and ethnicity which have potential direct effects) are wealth-related – population education, age, property size, and entitlement to free meals.

The statistically insignificant or positive relationship between lone-parents and performance is interesting. Gordon (1996) finds strong negative associations between non-employed lone-parents and GCSE secondary performance, and interprets these in terms of family structure effects. Here, looking at primary schools, the raw correlation between lone parents and school performance is certainly strongly negative. But, once we include other catchment area and school intake controls we find schools in areas with more lone parent households doing *better* than other areas. In fact, we need only control for the school proportion on free-school meals and the local proportion highly-qualified to get this result[14]. On its own, the lone-parent proportion is a powerful proxy for low income as measured by free-school meal entitlement, since many lone parents are benefit claimants[15]. This suggests that being a lone parent may not, by itself, damage a child's prospects in primary school – though having poorly educated, benefit-claiming parents does. Truancy, which mediates the effects of non-employed lone parents in Gordon's study, is probably less of an issue at primary school. We find no significant effect from lone parents in the IV, lagged performance models, but the coefficient remains positive.

5.5 How well do the catchment area characteristics measure intake characteristics?

Catchment area-based attributes are means for all households in the vicinity of the school, not just means of pupils' households. Regression estimates based on our imputed catchment areas will be downward biased relative to what we would get if we measured the

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[13] Tests on various components of the index entering individually in the regression confirm that the time-varying catchment area components – incomes, property prices and unemployment – are potentially endogenous, whereas the Census derived variables are not.
[14] If we restrict attention to variables at neighbourhood level, then age, qualifications, long-term sick rates and social housing drive the lone-parent coefficient to near-zero insignificance.
[15] The proportion of lone parents 'explains' around 50% of the variation in free-school meal entitlement in a simple OLS regression.

characteristics at school level if school intake is not drawn exclusively from the immediate neighbourhood. We should bear this in mind when reading the tables.[16]

Our catchment area incomes data and the free-school-meal entitlement (FSM) data at school level suggest a way to get a rough estimate of the extent to which the results based on catchment area averages reflect what we would find if we had the same characteristics for households of pupils at the school. This requires prediction of the proportion entitled to free school meals using the mean and standard deviation of neighbourhood incomes. Appendix C gives details of this method. We can then estimate school performance production functions of various specifications, using either predicted catchment area FSM entitlement or observed school-level FSM entitlement as regressors. With only school-type, age range, rural and LEA dummies the ratio of catchment area to school-level FSM coefficients is 0.902. If we include other school intake characteristics – the proportion with special needs and statements, and the proportion in minority ethnic groups, this ratio falls to 0.774. This means that in Table 2 to Table 5, the marginal effects could be up to 30% higher if we measured income (and other catchment area characteristics) at the school, rather than neighbourhood level. In Column 3 of Table 5 (which excludes school intake characteristics), the marginal effects are as much as 90% of the estimates we would get if we measured the characteristics at school level.

5.6 Local interactions and neighbourhood externalities

One reading of the evidence in Table 5 that catchment area characteristics matter over and above school intake characteristics is that there are spillover effects from the local community or from peers from other schools. This idea is reinforced if we restrict attention to the predicted catchment area proportion eligible for free school meals: this has an impact over and above free-school meal eligibility in the school, with a 10% reduction in the proportion of residents in poverty increasing school success rates by 1.7%. Of course, an equally plausible interpretation is that catchment area characteristics simply capture performance-related attributes of the school intake that are uncorrelated with free-school meal entitlement, educational needs and ethnic group. A more convincing argument is that if geographical interactions matter in the performance of primary schools, we should find that schools that perform well are clustered together and schools that perform badly are clustered

[16] The appropriate interpretation is that the estimates give the impact of local characteristics on the probability of a child reaching target attainment in a school, not the impact of own family characteristics or even own school intake characteristics on child attainment.

together, even taking into account the type of neighbourhood. We found this to be the case using descriptive statistics in Section 5.1. Estimation of the model in (1) with a spatially lagged dependent variable allows us to test more rigorously for these spatial interaction effects[17].

Table 6 shows the results of the spatial auto-regressions, for various choices of spatial lags. In the top panel, Column 1, we find a very low, though significant correlation of school performance with that of the nearest school. Performance also decreases with the distance to the nearest school. There is no reason to believe that all interaction effects will relate to the nearest school, which may well be a noisy measure of the relevant performance cluster. In Columns 2-5 the number of schools in the comparison group is increased from three to eighteen. The estimated correlation parameter rises to a maximum of nearly 0.1 when we consider the nearest nine schools[18], then falls away as the size of the group is increased. The effect of school dispersion is quite stable up to the nearest nine schools: an extra kilometre on average to the nearest schools reduces performance by 0.23 to 0.26 percentage points. This is not a very big effect, but is significant. The school distance effect, and the positive relationship with household density[19], is consistent with the maps we drew in Section 5.1 – schools in cities with high-density housing and with a high density of schools perform better than others. This is *not* attributable to the general rural/urban distinctions captured by a set of five dummy variables. The coefficients on these are not jointly or individually significant.

These will be inconsistent estimates of the interdependence of local school performance if there are unobserved area effects and because of feedback from own performance to performance schools in the comparison group. In the lower panel of Table 6 we instrument the spatially lagged school performance with the average of the school-type, age-range, and neighbourhood characteristics relating to the nearest schools. In Column 1, which relates to the nearest school only, the estimate is lost in the noise. In other columns, the spatial auto-regressive parameter falls slightly, but the difference between this and the upper panel is not significant[20], implying no unobserved area attributes that affect all local

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[17] The potential correlation between school characteristics and past performance is ignored and we use only census and school intake characteristics as regressors in the vector $\mathbf{x}_{s,t}$, which in any case tested as exogenous.

[18] Only one in three schools has this many neighbouring schools within a 2km radius, but three out of four schools have this many within a 4km radius.

[19] These are jointly significant, although household density is only significant at around the 10% level.

[20] In Column 4 the Hauseman test p-value is 0.427. The over-identifying restrictions on the spatially lagged instruments are also not rejected.

schools. When we look at the relationship with mean performance in the larger school clusters we find correlations of around 0.09. This small, but significant correlation between the performance of local schools indicates the existence of geographically localised spillover effects between schools, either through interactions between neighbouring pupils, or through inter-school technological spillovers. Changing school inputs to generate a ten percentage point improvement in the probability of target attainment by pupils generates an additional one percentage point improvement through feedback effects.

As noted, performance falls as mean distance to the nearest schools increases. This reinforces the case for spatial interaction effects, arising either through mutual imitation of teaching technologies, or through neighbourhood based peer-group effects. Higher school concentration can mean greater pooling of ideas, knowledge, and expectations amongst both pupils and teachers. Increased pooling in an environment of technological and human capital spillovers can only exert a positive influence on achievements, since it increases the range of options available and options with an expected negative impact need never be exercised. School density has been interpreted in other work as an indicator of the intensity of local competition between schools Bradley, *et al.* (1999). The indication here is that this localisation improves pupil achievement, though this could equally be through shared-technology and neighbourhood interactions as through 'competitive' effects.

5.7 Property effects on non-property owners

In Section 3.1, we considered how interaction between pupils and their neighbours, through role model effects, or expectations, might be detected through property-price effects on social tenants. Assuming that social tenant resources are uncorrelated with the resources of local owner-occupiers, we should find no relationship between property prices and school performance that is not mediated through the proportion of owner-occupier children in the school. We first test that this assumption is correct, using data from the Survey of English Housing, 1996-1999. The top panel of Table 10 shows coefficients obtained by regressing postcode sector mean household incomes of social tenants (council or housing association tenants) on the postcode sector mean incomes of other tenancy groups, with regional or local authority area dummy variables. The low coefficients and high standard errors confirm our expectation that incomes of the socially housed are locally uncorrelated across geographical space with the incomes of those in other tenancy groups. Incomes of social tenants living close to richer owner-occupiers are not significantly higher than the incomes of social tenants living in poor residential areas. The incomes of private tenants are, as we would expect, quite strongly associated with the incomes of owner-occupiers – see the lower panel. The distribution of homeowner incomes and private tenant incomes across space is determined by their demands for amenities and housing quality as reflected by prices and rents in the housing market.

If incomes of social tenants are unrelated to the incomes of owners and renters, there is no reason to expect the primary school attainments of social tenants to be related to local prices in the property market. Nevertheless, Figure 5 shows that property prices *are* related to school performance throughout the distribution of school tenancy group composition. The figure shows the kernel regression surface of mean Key Stage 2 performance (from 1996-1999) on log-mean property prices (in 1995) and the proportion of primary school age children in the school catchment area. Other linear controls in this semi-parametric estimator are school characteristics and local authority dummies. Schools in high house-price areas where nearly all children are social tenants achieve Key Stage 2 level 4 success rates which are 25 percentage points higher than similar schools in low-price areas. This relationship is not generated by reverse causality – the influence of school performance on property prices – since home-owners and renters will have no reason to bid up property prices in areas where nearly all the pupils are in social housing. Even at the top of the distribution of property prices, schools with low proportions of non-social tenant children struggle to reach the mean in terms of school performance.

Note, that the relationship between performance and local property wealth is, as we would expect, much stronger when the proportion of social tenants is low: moving from the bottom to the top of the property price distribution leads to a 35 percentage point improvement in performance, from around 50% success rates to around 85% success rates at Key Stage 2.

Estimation of the parametric version of this surface in equation (6), yields estimates of $l_1 = 0.072$ (t=4.758), $l_2 = 0.140$ (t=8.093)[21]: a 10% relative increase in local property wealth gives a baseline improvement of around 0.75 percentage points on the probability of success at Key Stage 2 – for all pupils, whether or not they are from home-owning households. The additional impact on non-socially housed tenants, those for whom property wealth has a direct impact through parental resources, is around 1.4 percentage points. In principle, we could estimate this model using instrumental variables for property prices and

[21] These are the marginal effects, not the coefficients.

the price-composition interaction. Property characteristics and interactions provide potential instruments. In practice, the results from this exercise implied that all property wealth effects on school performance were general effects across all tenancy groups, with no home-owner-specific components. Whilst the idea that property wealth effects are *purely* neighbourhood spillover effects that benefit all members of the community is interesting, it seems unlikely, and the results suggest some misspecification of the IV model[22].

5.8 Do teaching and resource inputs matter?

What about the key economic resources – pupil teacher ratios and expenditures? Do these influence pupil success in primary schools? The key problem in inferring causal effects is the geographical distribution of base-line pupil advantages, the allocation of resources and parental selection based on unobserved, idiosyncratic school effectiveness. Our detailed mapping of area characteristics to school locations and our panel structure present an ideal opportunity to address these issues. The estimates in Table 7 do just that. The first Column provides weighted least squares estimates of the association of performance with teaching inputs measured at the school level, and local authority expenditures per pupil. The specification includes LEA and time dummies, so the expenditure effect is identified off non-general changes within LEAs over time. With controls for school type, intake and neighbourhood status, we find positive effects from total LEA expenditure per pupil, but generally negative associations with the ratio of teachers to pupils. The only exception is for teachers on the 'other' category, which is made up of small numbers of student, 'licensed', unqualified teachers and language assistants[23]. School size has a separate negative impact, but this is very small in magnitude – a reduction of 0.5 percentage points for an extra one hundred pupils at the school.

The decrease in performance as we increase the number of teachers relative to pupils exemplifies the endogeneity issue – we cannot identify the causal effect of teachers on performance in the cross-section without knowledge of resource allocation policy and the parental selection process. Even controlling for observable school intake differences is insufficient to ensure exogeneity of the teaching inputs. However, taking deviations from the

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[22] Although tests of the exogeneity of property size from comparison of the (adjusted) coefficients in the school production model with and without lagged performance confirm exogeneity. The adjusted coefficients are equal in both models (*p*-value=0.883).

school averages over time – see Column 2 – we find that increases in qualified teacher-pupil ratios within schools over time *are* linked to increases in pupil attainments, but the coefficients on other teacher and staff types are not significant. The weakness of teacher effects is unsurprising, since it is well known that the within-group transformation reduces the signal to noise ratio and increases attenuation due to measurement error. We also lose the estimates on non-varying school attributes. A 1% increase in LEA expenditure increases the probability of Key Stage 2 target attainment by just over four percentage points.

Columns 3 and 4 implement the model of equation (3). By way of demonstration, in Column 3, lagged pupil achievement is un-instrumented. We should expect the estimated serial correlation parameter to be downward biased by the presence of unobserved components of lagged performance in the error term. The marginal effects of other variables are broadly similar to those in Column 1, though the coefficient on qualified teachers is now effectively zero. The final Column is the preferred specification, in which we condition on prior performance and instrument with performance in the year prior to this, as we did in the models in Table 5 and Table 6.

Instrumenting lagged performance almost doubles the inter-period correlation coefficient, from 0.436 to 0.828. As we saw before, school performance, even conditional on observable school and area characteristics, is highly persistent. The performance of a school, which is ten percentage points above the average *for a school of its type and intake*, can be expected to fall to five percentage points above similar schools after four years, and to one percentage point above similar schools after 12 years. This long decay makes clear the importance of *persistent* unobserved school-level characteristics. Important unobserved differences in intake quality are, however, unlikely given the controls we have available here[24]. We must infer that technologies at the school – technologies such as teaching practice, organisational structure, team cohesion, and leadership style – really can make a sustained difference to pupil achievement.

Taking out the components of teaching and resource inputs which are correlated with prior school performance allows us to make meaningful inferences about the causal effect of teacher and pupil numbers on pupil attainment. The ratio of both qualified and unqualified teachers to pupils *increases* the probability of pupil success. One extra qualified

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[23] Further investigations suggested that it is the student and licensed teacher types that drive the positive coefficient on this variable.
[24] Replacing the neighbourhood index with the full set of neighbourhood attributes makes no substantive difference to the results.

teacher in one hundred pupils at primary school improves the probability of target attainment at Key Stage 2 by 2.6 percentage points. Additional non-qualified teachers appear to have an even bigger impact, though the stock of 'other' teachers is less than 1% of the stock of qualified teachers, so the proportional impact of changes to the stock of qualified teachers is large by comparison. Administration staff and support teachers – support teachers for minority ethnic groups and the small percentage with statements of special education needs – do not have a significant impact on the performance of average pupils.

Primary schools do not appear to have an optimal size, unlike that found by Bradley and Taylor (1998) for secondary schools. In all the specifications, smaller is marginally better – a 0.05 percentage point improvement for ten less pupils – but the effect is statistically insignificant in the IV, lagged dependent variable specification. At the primary level, there are none of the economies of scale that might arise from the increased scope for teacher specialisation at secondary level.

It also worth noting that institutional factors – whether the school is a Community school, (funded and administered by the LEA), or whether it is Voluntary Aided, Voluntary Controlled or Foundation school (all mostly church schools) – have a significant impact on performance. Voluntary Aided and Foundation schools (which have their own admissions procedures) offer a four to five percentage point advantage over Community schools. Pupils in Voluntary controlled schools do slightly better than those in Community schools, though this advantage could be entirely attributable to parental selection effects since it is lost once we condition on past performance.

6. Summary and Conclusions

We have sought to explain geographical inequalities in primary school performance through direct effects from catchment area status and through local interactions between schools and pupils. We have also used our information on catchment areas and a school production function model with lagged dependent variable to investigate the dependence of intake and school resources on prior performance, and to re-evaluate the impact of teaching inputs and expenditures.

As we might have expected at the outset, there are strong relationships between pupil attainments and the characteristics of the catchment area in which the school is located.

Primary age pupils are more likely to reach target grades at age 11 in schools in higher income neighbourhoods, and the magnitude of this association is constant across regions. Geographical differences in performance are attributable to differences in underlying characteristics, not the sensitivity of performance to these characteristics. In 1999, a 10% increase in average incomes was associated with 2.5-percentage point improvement in Key Stage 2, Level 4 attainment rates. However, it is by no means dear that this is a causal relationship. After we allow for neighbourhood composition and residential selection on prior school performance, we find no evidence that average incomes influence school performance, although the well-known relationship between performance and pupil free school meal entitlement persists. Most of the relationship between performance and catchment area characteristics could be attributed to differences in the underlying attributes of the people who live there, rather than the incomes these people receive. An alternative view is that the important attributes – education, age and property size – pick up unobserved *permanent* income components, which are what really matters in terms of pupil achievements. We cannot differentiate between these two hypotheses here.

We get a clearer descriptive picture if we consider a single index of neighbourhood economic status that combines education, income and employment and demographic information. We can interpret this as a measure of unobserved latent neighbourhood quality or wealth. Pupils in schools that are one standard deviation above the average in terms of this index (including free-school meal entitlement) are around twenty percentage points more likely to achieve Level 4 in Key Stage 2 than those at one standard deviation below the mean, and the marginal returns to neighbourhood status are increasing. This is conditional on school ethnic composition and special educational needs, and allows for institutional differences, general differences between LEAs, and potential selection of residents on prior school performance. Differences in general catchment area status are evidently important determinants of success in schools.

Summary statistics of spatial correlation in school performance reveal that good primary schools tend to be located near other good primary schools and bad schools near other bad schools. This is what we would expect if school performance is in any part determined by the characteristics of pupils and their families, and if these characteristics exhibit spatial autocorrelation. What is interesting here, is that this clustering remains, even after controlling for the characteristics of schools and catchment area residents. What we have shown is that primary school performance is not only related to the spatial distribution of area characteristics, but that it actually *depends* on the performance of local schools. This spatial dependence could be a neighbourhood human capital spillover, operating through social interaction of pupils from neighbouring schools, or a knowledge spillover in terms of teaching technologies. Schools also perform better if they are near other schools, and in areas of higher household density. This, and inspection of maps of residual performance (after adjustment for pupil disadvantages), implies that city schools are more effective than others. This clustering of school effectiveness in cities hints at a role for spillover effects in human capital production in the urban environment: these areas do *better* than other areas with similar levels of intake poverty. The larger pool of employment opportunities in the city may also attract better teachers. Evidence of an underlying sensitivity of school performance to property prices, regardless of the proportion of home-owner/private tenant pupils, reinforces the impression of neighbourhood spillovers: home-owner/private tenant wealth influences the outcomes of social tenants, either through social interactions of children or by enhancing life expectations.

Naïve inference using the English primary school data would lead us to conclude that increasing the number of teachers in schools would worsen pupil attainments, even conditional on school intake measures related to poverty and educational needs. Removing the variation in school performance that is attributable to community characteristics weakens these associations but is insufficient to change their sign. This is an unexpected result, since such negative associations are often attributed to area-based resource allocation. However, we find significant positive effects on teacher inputs once we properly condition on lagged school performance, or work with differences over time. Local education authority level expenditure per pupil has weakly positive effects on performance in all specifications.

Despite these measured positive effects of observable economic resources, their influence dominated the influence of community and location. What is the relative contribution of teaching resources and school intake to school performance? Clearly, any answer to this depends on what characteristics we define as resource inputs and which we assume are neighbourhood or intake characteristics. What's more, the result will depend on the number of characteristics and the accuracy in measurement of these variables. Nevertheless, it seems worthwhile trying to make some statement on this issue, based on the characteristics that are significant in the preferred specification (Column 4 in Table 7) and that we can reasonably categorize as either resource or neighbourhood inputs. The model partial sum of squares attributable to observable intake factors – proportion on free-school meals, proportion non-white, the neighbourhood index and rural-urban indicators is 57.74. For observable resource-related factors – teacher-pupil ratios, LEA expenditure and school type – the partial sum of squares is 10.86. These figures only relate to variation in the data that is unrelated to prior school performance. By this calculation, intake and neighbourhood currently explain around five times as much of variance in primary school performance than do these basic observable resource inputs and school types. This result is hardly changed if we include school age range and size in the school resource set. Of course, there may be plenty of unobserved characteristics of either category, but the indication here is that the background of pupils and the neighbourhood context of the school dominates in explaining the variation in school performance.

Another way of looking at this is in terms of anticipated impacts of changes in the input factors, using the marginal effects in Table 7. On this basis, a one standard deviation increase in the number of qualified teachers per 100 pupils (0.486 in 98/99) would increase average school performance by around 1.3 percentage points. This implies an extra 18,000 qualified teachers! By comparison, a one-quarter standard deviation decrease in the proportion of pupils eligible for free school meals (4% of the school population or about 150,000[25]) could increase school performance by 1.8 percentage points, since the marginal effect (unreported in the table) is –0.461. Assuming a qualified primary school teacher's starting salary of around £20,000 per year[26], the cost of the first change would be around £360 million. This is equivalent to £2400 per year for each family of the 150,000 children we needed to get off free-school meals to provide a comparable performance change. In terms of LEA expenditure, an additional 10% (£180) on current expenditure per pupil would cost around £684 million, providing an performance improvement of only 0.4 percentage points on average.

The reasons for the link between pupil attainments and location are not identified in this work. It is almost tautological to say that some sort of disadvantage of pupil family background is the underlying factor. Still, we do not know whether this operates through abilities, a poor home environment for learning, bad peer group influences, or through the impact of deprivation on the organisational effectiveness of schools. Lupton (2001), for example stresses that poor performance in disadvantaged areas may be a result of the diversion of resources to tackling behavioural and attendance problems, strain on staff-management relations and staff recruitment difficulties.

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[25] The number of primary school children in 1999 was around 3.8 million.

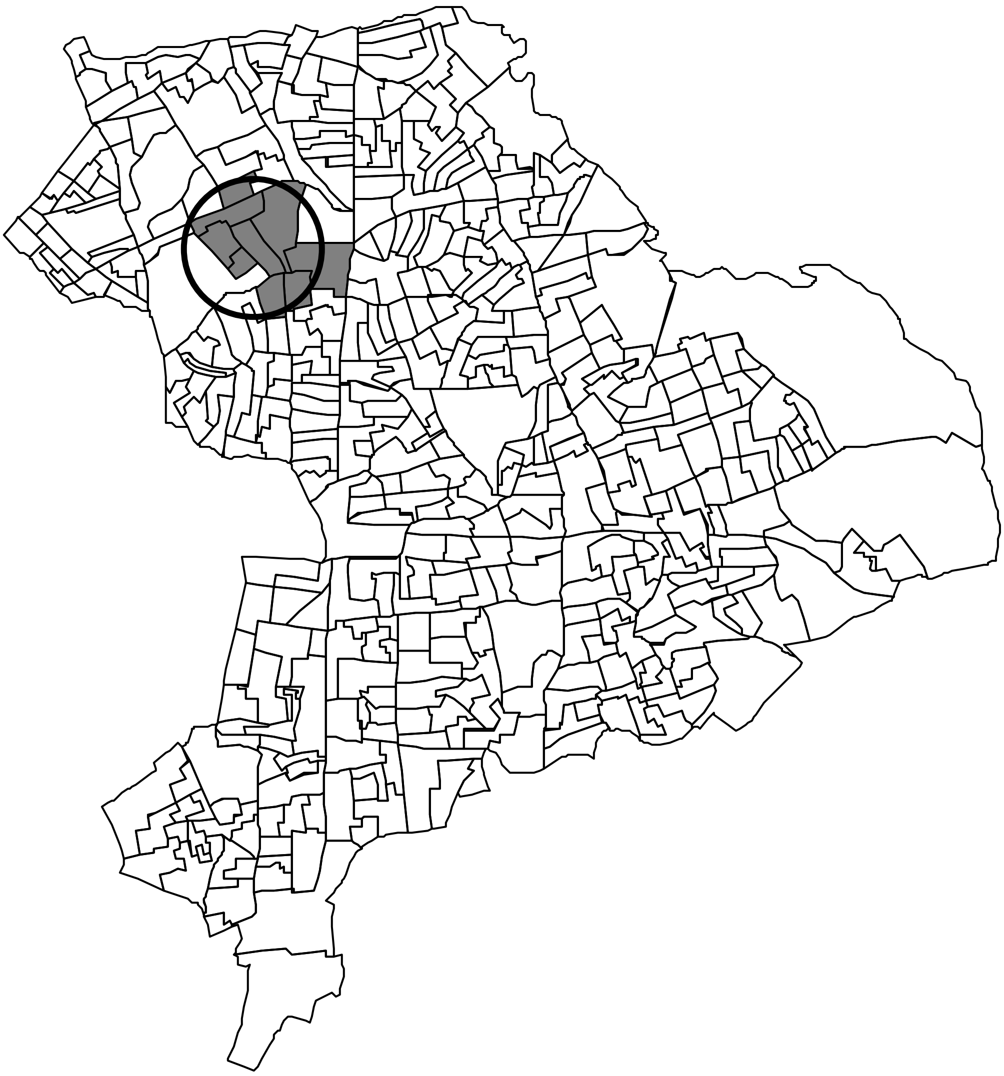
[26] Range of starting salaries: £16,038 - £24,843, dependent on qualifications, age on entry and prior relevant experience (Salary data collected April 2001). Range of salaries at age 40: £24, 843 - £35,648 (classroom

Area disadvantage is not a sufficient condition for poor pupil attainments, but ineffective school organisation in an environment of pupil disadvantage can be. Although the impact of *observed* resource inputs is small, there is still a substantial amount of school level variation in performance left unexplained. It is likely that much of this is systematically related to unobserved school-level processes – the leadership qualities of the head and teaching practice in the school, for example – but our national school-level data is fairly silent on these issues. School effectiveness studies attribute between 8-18% of variation in *pupil* attainments to idiosyncratic school level factors at secondary level (see, for example White and Barber, 1994, p.85). The strength of the relationship we observe between voluntary-aided status and primary performance – even conditional on past performance and school intake – indicates a strong role for organisational differences and school ethos, unless these schools really are selecting pupils on the basis of attainment-enhancing characteristics that we just do not observe. The performance advantage suggests these, primarily religious, schools do employ more effective technologies than Community schools. Some of these differences may be attributable to unobserved aspects of the composition of their intake – Coleman (1988), for example, suggests a role of social capital effects in Catholic schools in the US – but this seems unlikely given the robustness of institutional differences to conditioning on past performance.[27] More generally, idiosyncratic unobserved school performance is highly persistent from year to year – even conditional on a wide range of community and intake measures – implying a strong role for systematic school level factors.

teacher) (Salary data collected April 2001). Source CSU/AGCAS Career Services Unit/Association of Graduate Careers Advisory Services.

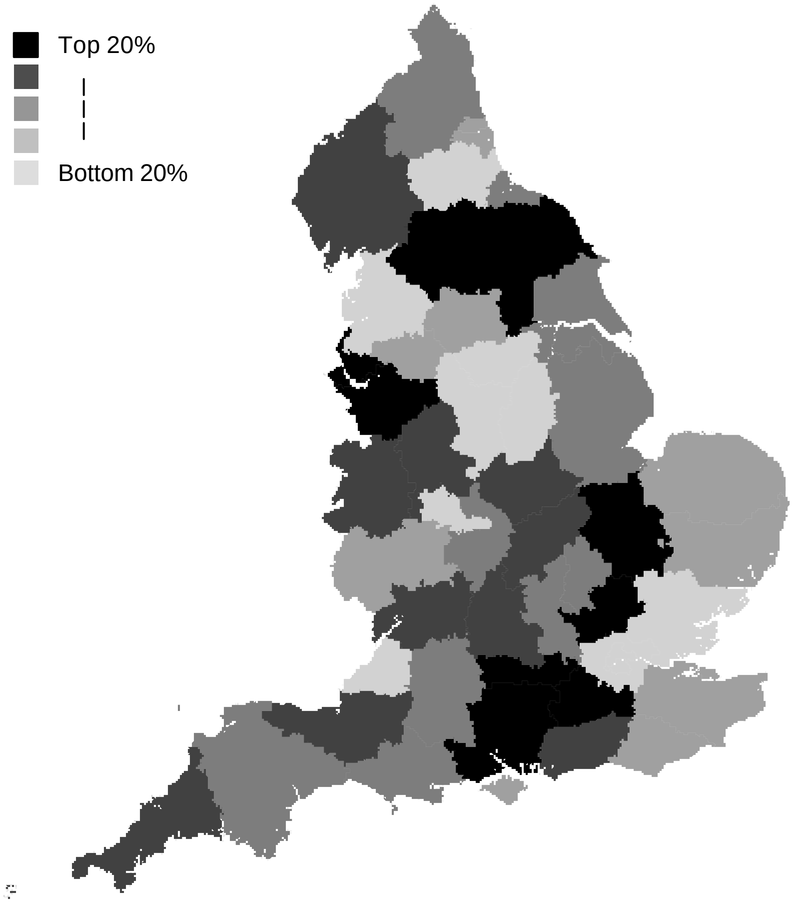
[27] This effect at secondary level is, of course, the justification for the proposed expansion of the church-school sector proposed in the Government's White Paper on education (DfES, 2000, p. 45). The widely discussed implications of this for equity of educational provision across ethnic groups need not be repeated here.

Figure 1: Illustrative pseudo-catchment area matching on Census Enumeration Districts for a school in Hackney, London



Scale: circle diameter approximately 0.8km

Figure 2: a) Quintiles of KS2 scores, by English county, 1999



b) Quintiles of KS2 scores, adjusted for free-school meal entitlement, 1999

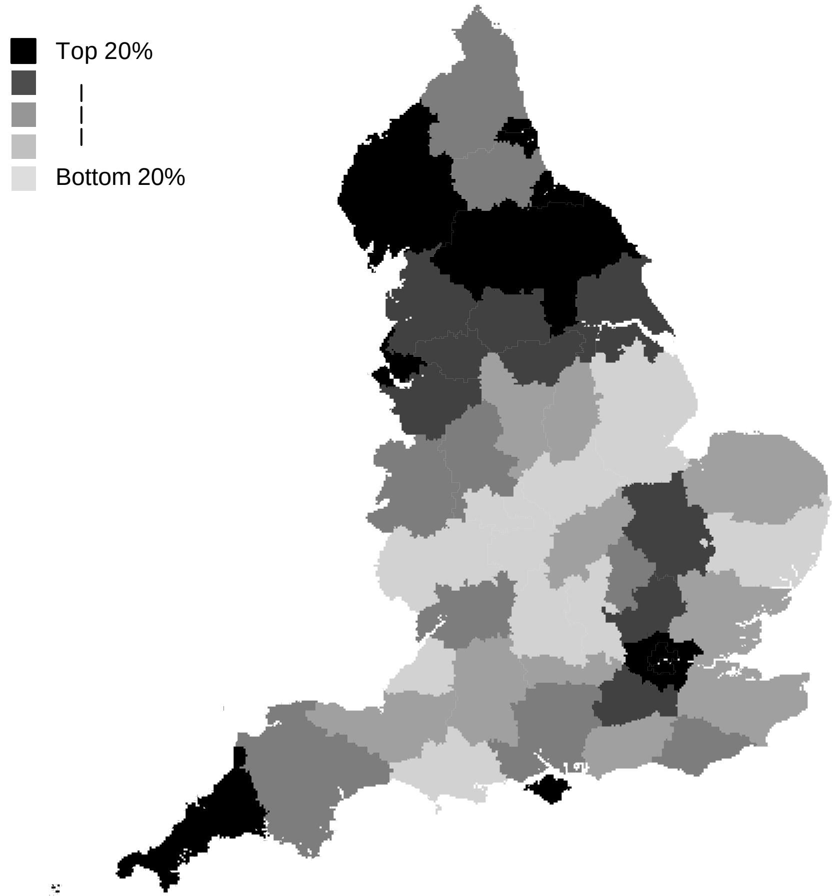
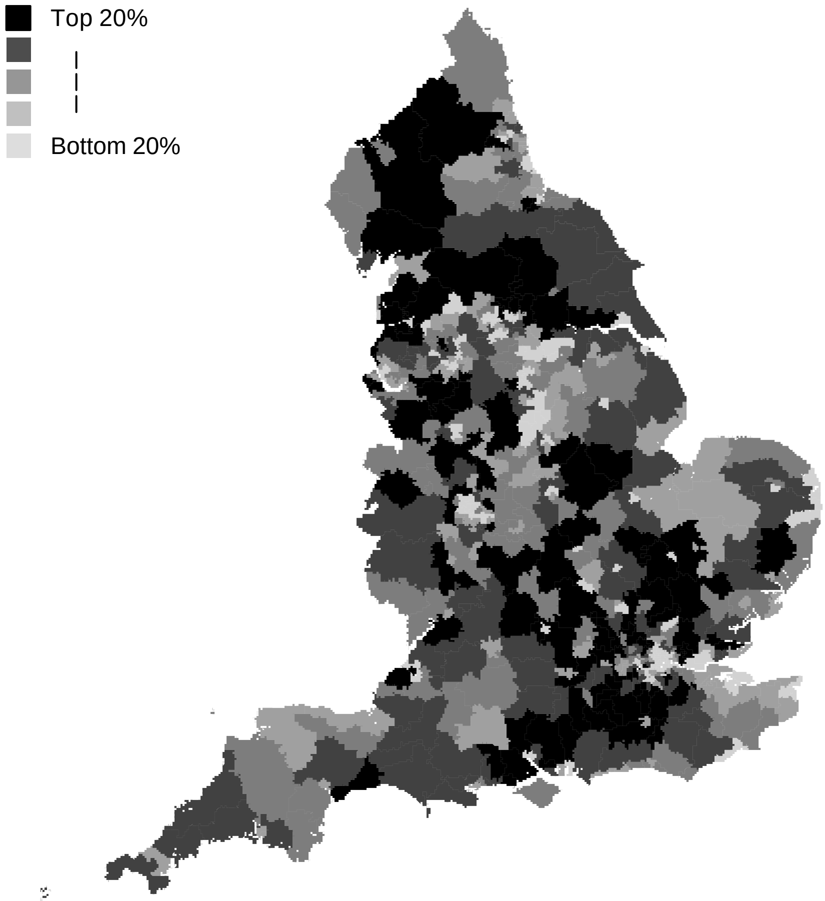


Figure 3: a) Quintiles of KS2 scores, by Parliamentary Constituency



b) Quintiles of KS2 scores, adjusted for free-school meal entitlement

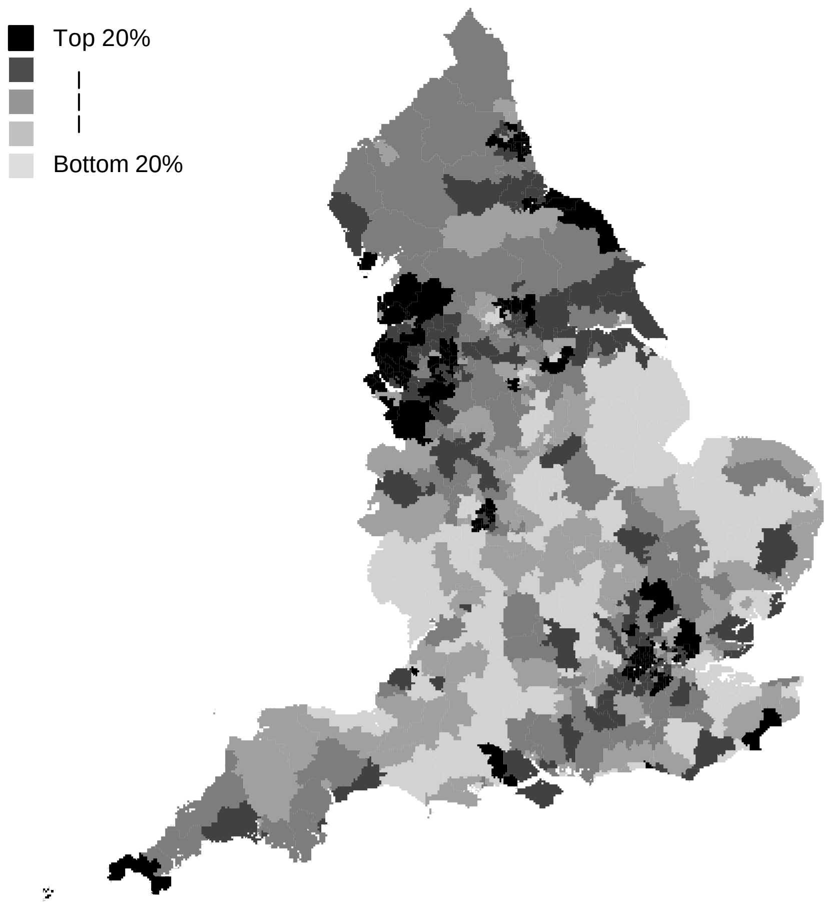
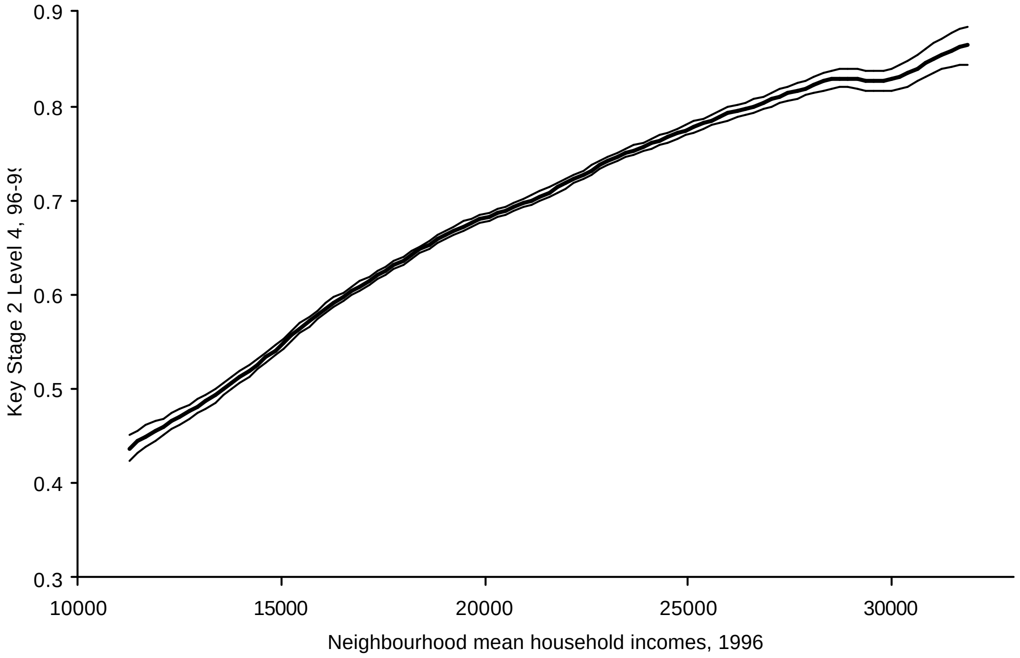


Figure 4: Primary school performance and catchment area characteristics

Incomes:



Unemployment:

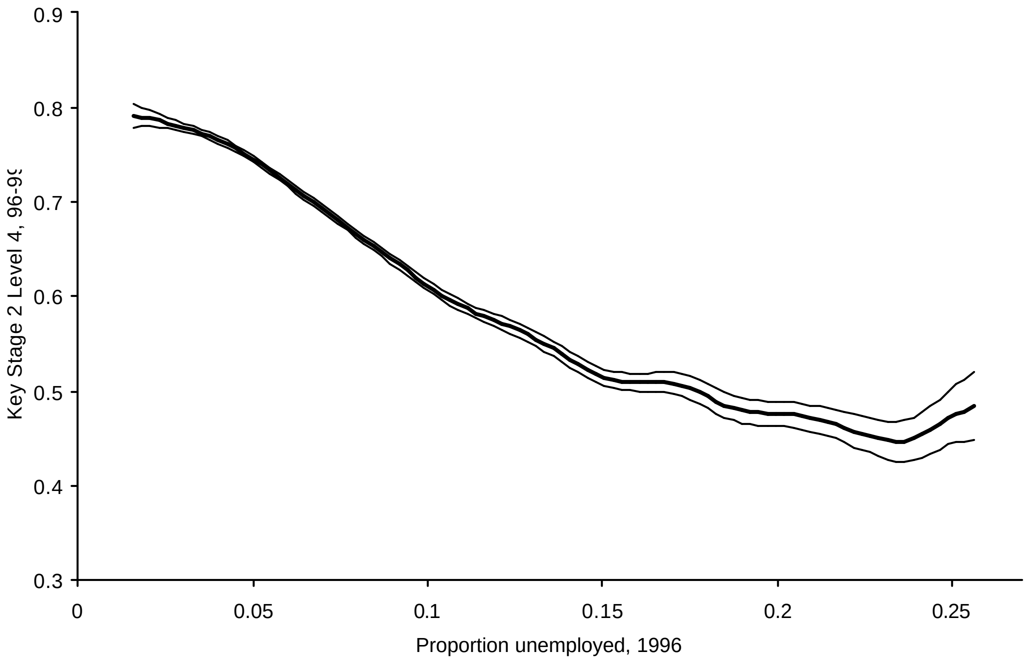


Figure shows kernel regression of mean proportion achieving level 4 in Key Stage 2 tests on mean catchment area incomes or proportion unemployed. Additional controls are school-type, age-range, rural-urban, and LEA dummies. Thin lines show pointwise 95% confidence intervals for kernel regression line.

Figure 5: Relationship between primary school performance, local property prices and social-tenant children, 1996-1999

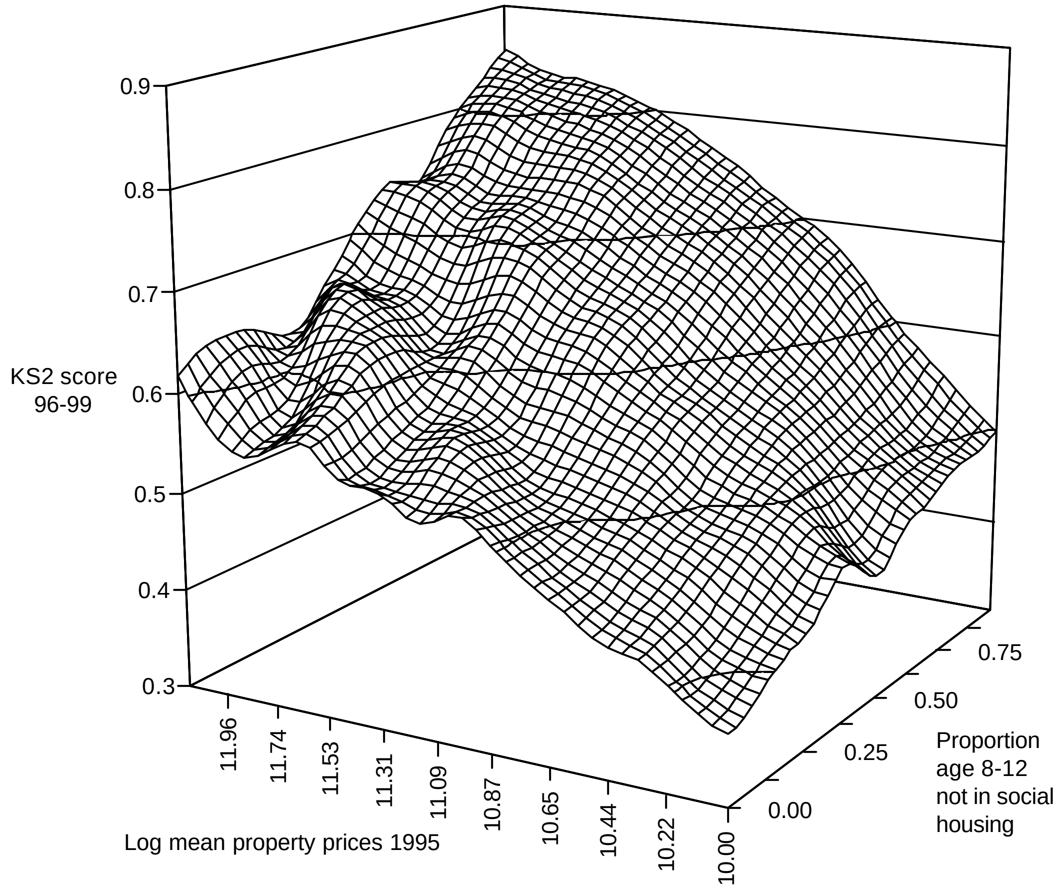


Figure shows kernel regression surface of mean Key Stage 2 level 4 achievement, 1996-1999, on log-mean local property prices and local proportion of non-socially housed 8-12 year olds. Controls are local authority dummies, school type, age-range and rural/urban category dummies.

Kernel: Gaussian, bandwidth matrix = 0.25*variance-covariance matrix of regressors. Cholesky decomposition of bandwidth matrix = { 0.098, 0.017 \ 0, 0.057 }

N = 11571, Overall R2 = 0.535

Table 1: Rank adjacency statistics, Key Stage 2 performance measures, 1996-1999 mean

		Unadjusted		LEA adjusted		PTR/type adjusted		Free meals adjusted	
Region	N	D	z-score	D	z-score	D	z-score	D	z-score
NR	725	211.367	-4.948	215.013	-4.360	193.880	-7.773	230.891	-1.795
NW	2271	564.925	-17.544	600.415	-14.307	572.419	-16.860	700.396	-5.192
YH	1405	332.290	-15.628	359.329	-12.529	336.652	-15.128	413.462	-6.326
EM	1182	293.731	-12.639	319.145	-9.446	291.756	-12.887	344.041	-6.318
WM	1436	339.298	-15.857	375.067	-11.797	343.728	-15.355	412.639	-7.533
SW	1356	377.741	-8.748	392.972	-6.882	380.440	-8.335	395.876	-6.545
E	1347	333.388	-13.522	354.379	-11.074	340.943	-12.641	387.676	-7.191
L	1509	398.234	-11.775	449.255	-6.059	376.464	-14.215	433.492	-7.825
SE	1823	478.776	-12.946	515.901	-9.227	477.756	-13.048	536.603	-7.153

NE: North East, NW: North West, YH: Yorkshire and Humberside, EM: East Midlands, WM: West Midlands, SW: South West, E: Eastern, L: London, SE: South East

Expected score is (N+1)/3

Weights based on indicators of nearest school.

Adjusted scores are residuals from regressions.

Table 2: School sensitivity to neighbourhood conditions by region, 1996-1999

		1996	1997	1998	1999	Sample
North East	Log hh income	0.379 (6.887)	0.308 (14.356)	0.313 (8.947)	0.226 (6.887)	601
	Unemployed per hh	-0.773 (-2.020)	-0.866 (-5.399)	-0.877 (-2.894)	-0.907 (-2.020)	
North West	Log hh income	0.430 (14.540)	0.366 (13.602)	0.310 (10.687)	0.245 (14.540)	2053
	Unemployed per hh	-0.580 (-3.850)	-0.452 (-1.864)	-0.638 (-3.031)	-0.479 (-3.139)	
Yorks and Humberside	Log hh income	0.435 (9.768)	0.318 (6.117)	0.358 (7.976)	0.328 (6.700)	1187
	Unemployed per hh	-0.545 (-3.140)	-0.575 (-2.373)	-0.342 (-1.579)	-0.189 (-0.798)	
East Midlands	Log hh income	0.487 (8.127)	0.414 (7.708)	0.457 (9.032)	0.308 (6.779)	932
	Unemployed per hh	-0.239 (-0.847)	-0.055 (-0.164)	-0.174 (-0.461)	-0.453 (-1.405)	
West Midlands	Log hh income	0.490 (12.233)	0.405 (8.108)	0.423 (12.597)	0.340 (10.572)	1255
	Unemployed per hh	-0.647 (-3.584)	-0.475 (-1.974)	-0.112 (-0.404)	-0.129 (0.807)	
Eastern	Log hh income	0.326 (3.720)	0.306 (3.685)	0.300 (5.943)	0.234 (5.835)	1105
	Unemployed per hh	-0.916 (-1.865)	-0.774 (-1.621)	-0.843 (-2.103)	-0.268 (0.848)	
London	Log hh income	0.394 (8.280)	0.251 (5.452)	0.239 (4.057)	0.247 (5.643)	1403
	Unemployed per hh	-0.551 (-2.911)	-0.672 (-2.658)	-0.530 (-2.610)	-0.368 (-1.769)	
South East	Log hh income	0.363 (4.382)	0.361 (5.531)	0.300 (8.181)	0.227 (5.565)	1573
	Unemployed per hh	-0.382 (-1.448)	0.052 (0.188)	0.022 (0.062)	0.003 (0.012)	
South West	Log hh income	0.405 (7.183)	0.374 (8.439)	0.378 (7.243)	0.266 (5.441)	1080
	Unemployed per hh	-0.393 (-2.142)	-0.171 (-0.819)	-0.074 (-0.245)	-0.327 (-1.279)	
Mean KS2		0.585	0.655	0.649	0.734	

Marginal effects and t-statistics reported.
Regressions include LEA dummies, school-type dummies, age-group dummies, rural-urban indicators, proportion in school with statements of special educational needs, other special educational needs and non-white ethnic groups.

Table 3: School sensitivity to catchment area status index by region, 1996-1999

Region	1996	1997	1998	1999	Sample
North East	0.117 (18.182)	0.108 (31.555)	0.105 (12.516)	0.091 (15.318)	601
North West	0.111 (17.103)	0.098 (26.483)	0.094 (17.624)	0.078 (14.223)	2053
Yorks and Humberside	0.131 (22.988)	0.113 (18.398)	0.109 (18.487)	0.106 (15.744)	1187
East Midlands	0.138 (13.331)	0.125 (7.995)	0.137 (10.505)	0.114 (9.764)	932
West Midlands	0.133 (11.359)	0.117 (8.867)	0.106 (8.555)	0.096 (10.695)	1255
Eastern	0.118 (13.986)	0.124 (24.178)	0.128 (11.448)	0.102 (18.577)	1105
London	0.107 (8.016)	0.100 (14.286)	0.100 (12.662)	0.104 (12.260)	1403
South East	0.129 (14.619)	0.128 (7.985)	0.114 (9.641)	0.096 (11.663)	1573
South West	0.135 (23.447)	0.104 (10.906)	0.117 (10.237)	0.094 (11.914)	1080

Reported parameter is response to unit change (one standard deviation) in standardised neighbourhood index.

Index is first factor in factor analysis of log mean incomes, unemployment rate, log mean property prices, quadratic in proportion eligible for free school meals. Proportion of variance explained by this factor is 85-90%.

Regressions include LEA dummies, school-type dummies, age-group dummies, rural-urban indicators, proportion in school with statements of special educational needs, other special educational needs and non-white ethnic groups.

Table 4: Catchment area status and primary school performance, 1998 & 1999

	OLS	OLS	IV	IV	Means
$\hat{r}$	-	-	0.811 (52.281)	0.830 (58.118)	
Index of neighbourhood status	0.037 (13.004)	-	0.037 (4.136)	-	0.000
Index squared	0.012 (8.090)	-	0.018 (4.186)	-	1.000
Index of neighbourhood status with free-school meals	-	0.109 (41.259)	-	0.102 (8.055)	0.000
Index squared	-	0.021 (14.981)	-	0.024 (4.996)	1.000
Pupils eligible for free school meals	-0.870 (-27.547)	-	-0.744 (-7.660)	-	0.196
Pupils eligible for free-school meals squared	0.623 (13.343)	-	0.431 (3.361)	-	0.069
Pupils with statements	-0.752 (-11.042)	-0.956 (-13.371)	-1.187 (-5.236)	-1.669 (-5.250)	0.017
Others with special needs	-0.236 (-15.084)	-0.402 (-24.274)	-0.228 (-4.046)	-0.355 (-5.348)	0.194
Non-white ethnic group pupils	-0.037 (-4.414)	-0.059 (-5.247)	-0.057 (-0.125)	-0.078 (-2.823)	0.087
R2	0.592	0.567	0.600	0.593	
Hauseman test p -value				0.170	

Sample size: $N=11189 \times T=2$

All models include LEA (145), rural-urban (5), school type(3), age-range (4) dummies and full-time equivalent pupils numbers, 1999 dummy.

Instrument in Column 4 is second time lag of dependent variable. All parameters (except ρ) are marginal effects at the mean. Lagged dependent variable parameters are multiplied by $(1-\rho)^{-1}$

Estimates of catchment area/free school meals index parameters without controls for special needs and ethnicity are Index: 0.134 (8.826) Index^2: 0.028 (4.991) in lagged dependent variable model.

For definition of catchment area indices see the Appendices.

Table 5: Catchment area characteristics and primary school performance, 1998 & 1999

	OLS	OLS	IV	IV	Means
$\hat{r}$	-	-	0.876** (71.534)	0.798** (48.385)	
Catchment area:s					
Log mean local household incomes	0.092** (4.802)	0.045** (3.111)	-5.0e-03 (-0.064)	-7.8e-03 (-0.169)	9.924
Log mean local property prices in previous year	0.016 (1.884)	0.013 (1.882	3.1e-03 (0.075)	7.0e-03 (0.290)	11.159
Local unemployment claimants per household	-0.555** (-5.929)	0.130 (1.885)	-0.488 (-1.316)	0.224 (1.012)	0.055
Aged 8-12 not in social housing in 1991	0.106** (7.945)	0.023* (2.431)	0.112* (2.466)	0.027 (0.979)	0.720
Higher educated over-18s in 1991	0.323** (10.596)	0.277** (11.539)	0.275* (2.343)	0.244** (3.446)	0.119
Average age of population in 1991	0.011** (13.359)	3.9e-03** (5.744)	0.013** (3.554)	4.9e-03* (2.231)	36.691
Economically active men 25-34 in 1991	0.126* (2.185)	8.1e-03. (0.200)	-0.043 (-0.151)	-0.098 (-0.562)	0.958
Economically active women 25-34 in 1991	0.019 (0.725)	-0.029 (-1.404)	-0.057 (-0.659)	-0.069 (-1.299)	0.650
Lone parents households in 1991	0.075 (0.784)	0.197** (2.890)	0.214 (0.635)	0.234 (1.186)	0.045
Proportion of households with dependant children	0.252** (6.089)	0.106** (3.536)	0.197 (1.243)	0.077 (0.782)	0.323
Long term sick rate in 1991	-0.704** (-7.474)	0.061 (0.910)	-1.220** (-3.508)	-0.191 (-0.917)	0.126
One-year migrants in 1991	0.150** (2.696)	0.068 (1.526)	-0.029 (-0.125)	-0.040 (-0.282)	0.065
Average rooms in owner-occupier hhs in 1991	0.015** (3.230)	9.4e-03** (2.720)	0.037* (2.224)	0.021* (2.126)	5.392
Households (1000s) per km^2 in 1991	9.1e-04 (0.706)	2.3e-03* (2.332)	1.7e-03 (0.360)	2.8e-03 (1.052)	2.337
Agricultural employment in 1991	-0.193** (-3.035)	-0.075 (-1.425)	-0.211 (-1.089)	-0.086 (-0.710)	0.015
School level:					
Pupils eligible for free school meals	-	-0.919** (31.790)	-	-0.956** (-8.334)	0.196
Pupils eligible for free-school meals squared		0.694** (16.111)		0.772** (5.286)	0.069
Pupils with statements	-	-0.776** (-11.811)	-	-1.154** (-5.542)	0.017
Others with special needs	-	-0.228** (-16.194)	-	-0.206** (-3.905)	0.194
Non-white ethnic group pupils	-	-0.055** (-5.726)	-	-0.075** (-2.824)	0.087
R2	0.498	0.602	0.575	0.605	

Sample size: N=11189 $\times$ T=2

All models include LEA, rural-urban, school type, age-range dummies and full-time equivalent pupils numbers.

Instrument in Column 4 is second time lag of dependant variable. All parameters (except ρ) are marginal effects at the mean.

* significant at the 5% level, ** significant at 1% level.

Table 6: Primary school interaction effects

	J=1	J=3	J=6	J=9	J=18
Spatial lags not instrumented					
Mean performance in nearest J schools primary schools	0.016 (2.234)	0.086 (4.480)	0.084 (5.747)	0.099 (6.212)	0.059 (5.068)
Mean distance to nearest J schools in kilometres	-2.3e-03 (-2.334)	-2.3e-03 (-2.732)	-2.6e-03 (-3.540)	-2.3e-03 (-3.535)	-1.3e-03 (-2.504)
Households per km^2 (1000s)	1.8e-03 (1.987)	1.9e-03 (1.988)	1.7e-03 (1.771)	1.7e-03 (1.840)	1.8e-03 (1.900)
Rural-urban location, *p*-value	0.279	0.263	0.181	0.214	0.315
R^2	0.590	0.591	0.591	0.592	0.591
Spatial lags instrumented					
Mean performance in nearest J schools primary schools	5.5e-03 (0.430)	0.076 (3.091)	0.073 (3.491)	0.086 (3.816)	0.057 (3.000)
Mean distance to nearest J schools	-2.3e-03 (-2.365)	-2.3e-03 (-2.699)	-2.5e-03 (-3.427)	-2.2e-03 (-3.352)	-1.2e-03 (-2.439)
Households per km^2 (1000s)	1.8e-03 (1.904)	1.9e-03 (1.972)	1.7e-03 (1.768)	1.7e-03 (1.835)	1.8e-03 1.902
Rural-urban location, *p*-value	0.287	0.267	0.194	0.231	0.323
R^2	0.590	0.591	0.591	0.591	0.591

Sample size: $N=11189 \times T=2$

All models include LEA dummies, proportions: eligible for free school meals, for free school meals squared, with statements, with other special educational needs, non-white ethnic groups, non-socially housed, the number of FTE pupils, neighbourhood wealth index and index squared, school type, age-range.

Household density and school distance are always jointly significant at the 1% level at least.

Instruments are spatial lags (mean in nearest *J* schools) of school type, age-range, non-socially housed pupils and neighbourhood index (means of 98-99 if time varying).

Table 7: Resources, school structure and primary school performance, 1998 & 1999

	OLS	W-G	OLS	IV	Means
$\hat{r}$	-	-	0.436 (63.176)	0.828 (58.302)	-
Qualified teachers/100 pupils (fte)	-0.094 (-3.066)	8.3e-03 (2.827)	-3.6e-03 (-0.952)	0.026 (2.356)	4.219
Other teachers/100 pupils (fte)	0.021 (2.154)	3.0e-03 (0.478)	0.036 (2.986)	0.115 (3.452)	0.036
Support teachers/100 pupils (fte)	-6.2e-03 (-2.776)	-4.9e-04 (-0.224)	-5.8e-03 (-2.106)	-4.1-03 (-0.499)	0.780
Administration staff/100 pupils (fte)	-0.015 (-1.893)	1.3e-03 (0.172)	-0.013 (-1.381)	-4.7e-03 (-0.174)	0.423
Log total LEA expenditure per primary school pupil	0.036 (2.773)	0.041 (3.212)	0.039 (2.293)	0.042 (1.980)	7.473
Full time equivalent pupils (100s)	-5.3e-03 (-4.844)	2.0e-4 (-4.392)	-5.3e-03 (-3.850)	5.4e-03 (-1.368)	2.783
Foundation	0.036 (6.404)	-	0.038 (5.160)	0.049 (2.210)	0.023
Voluntary Aided	0.047 (16.845)	-	0.048 (13.534)	0.052 (4.899)	0.233
Voluntary Controlled	0.015 (4.663)	-	0.012 (3.048)	-0.003 (-0.222)	0.112
Age range	0.0000	-	0.0000	0.1894	-
Year = 1999	0.087 (70.705)	0.101 (72.591)	0.091 (57.947)	0.093 (46.983)	-
R^2	0.577		0.665	0.594	

All models (except Column 2) include LEA dummies, rural-urban dummies, proportions: eligible for free school meals, with special educational needs, with statements of SEN, non-white, plus an index of neighbourhood status.

Instrument in Column 4 is second time lag of dependant variable. All parameters (except ρ) are marginal effects at the mean.

Expenditure elasticity alone is: Column 1: 0.037 (t=2.740), Column 2: 0.042 (t=3.320), column3: 0.042 (t=2.068), Column 4: 0.043 (t= 1.878).

Appendix A

Formally, each school with postcode grid reference c_{1s}, c_{2s} is assigned catchment area characteristics estimated by:

$$\bar{\mathbf{x}}_{\mathbf{s}} = \sum_{k}^{N} q_k \mathbf{x}_{\mathbf{k}} \text{ where } q_k = \begin{cases} \frac{p_k}{P_K} \text{if } k \in M \\ 0 \text{ otherwise} \end{cases}$$

p_k is the number of 0-4 year olds in the 1991 census enumeration district, $P_K = \sum_{k \in M} p_k$ and the set M is defined by:

$$M = \left\{k : \left[(c_{1k} - c_{1s})^2 + (c_{2k} - c_{2s})^2\right] \leq \left[(c_{1K} - c_{1s})^2 + (c_{2K} - c_{2s})^2\right]\right\}$$

K is the index of the K^{th} enumeration district in the spatial data set, where observations are ranked according to their inverse distance from the school location:

$$d^{-1} = \left[(c_{1k} - c_{1s})^2 + (c_{2k} - c_{2s})^2\right]^{-0.5}$$

The number of nearest neighbours is taken as

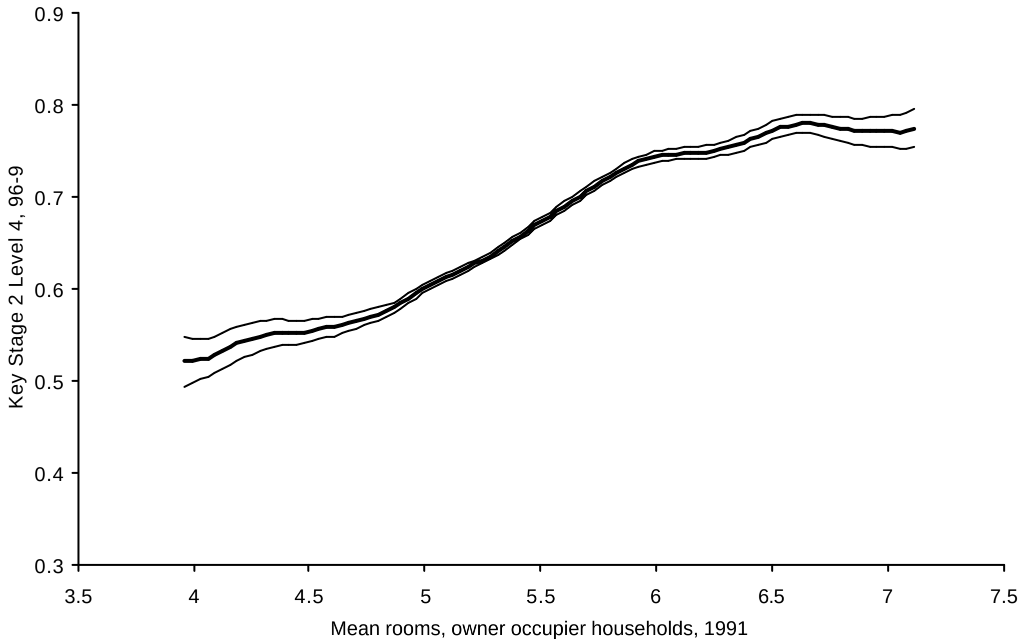
$$K = \frac{P_0}{5P_s}$$

where P_s is the number of pupils in the year-6 (age-11) cohort in 1999, and P_0 is the number of 0-4 year olds (5 cohorts) in the nearest 8 enumeration distircts in 1991. Similar techniques applied to the school performance scores give us estimates of the mean performance in the nearest J schools, for a number of choices of J. A cluster of seven primary schools[28] is probably at the top end of what most people would consider as a school neighbourhood, and that a family in a typical neighbourhood might consider for their child. This is also the median number of schools within a 1km radius.

[28] And this corresponds to a first-order grouping on an equilatral triangular lattice

Appendix B

Figure 6: Performance and local property size



Appendix C

A.1 Constructing the neighbourhood proportion on free-school meals

We want to construct an estimate of the proportion of households entitled to free school meals based on the distribution of incomes in the constructed catchment area, so that we can compare results using this, and using the school-level data. Assume that the distribution of incomes in catchment area of school s is lognormal with mean m_s and variance $s^2{}_s$. Our data gives us mean and standard deviation of household incomes in the catchment area, not log-incomes, so we must estimate the mean and variance of the distribution of log incomes in each catchment area:

$$\hat{m}_s = \ln \overline{m}_s{}^2 - 0.5 \ln\left(\overline{m}_s^2 + s_s^2\right), \qquad \hat{s}_s^2 = \qquad (7)$$

where $\overline{m}_s$ and s_s are the sample mean and standard deviation of household incomes in catchment area of school s (see, for example, Greene (1997, p. 60). The proportion in a catchment area entitled to free school meals is then:

$$\text{Prob}_s(m \le a) = \Phi\left(\frac{\ln a + \ln \overline{\overline{m}} - \hat{m}_s}{s_s^2}\right) \qquad (8)$$

assuming all households with incomes less the a times population mean incomes $\overline{\overline{m}}$ are entitled. We can obtain an estimate of $\ln a$, and obtain the catchment area predicted proportion entitled to free school meals (FSM), by the constrained weighted least squares regression:

$$\Phi^{-1}(p_s) = a \cdot 1/\hat{s}_s^2 + \left(\ln \overline{\overline{m}} - \hat{m}_s\right)/\hat{s}_s^2 + w_s \qquad (9)$$

with standard grouped-probit weights. Our estimate of $\ln a$ is -0.596 (1.4e-03), implying that households on incomes below about half-mean national household income are entitled to free school meals.[29]

[29] An alternative approach is to adjusting a until the means in the catchment area and school distributions are equal to within some close tolerance. This gives nearly identical results.

Appendix D

Table 8: Factor loadings and scoring coefficients for neighbourhood status

Variable	Loading	Coefficeint	Loading	Coefficient
Free school meals	-	-	-0.877	-0.207
Free-school meals squared	-	-	-0.815	-0.060
Log mean incomes	0.782	0.066	0.748	0.154
Log mean property prices	0.740	0.180	0.597	0.034
Unemployed claimants per hh	-0.766	-0.065	-0.781	-0.057
Aged 8-12 not social housed	0.780	0.110	0.788	0.082
Higher educated	0.669	0.041	0.635	0.029
Mean population age	0.405	0.148	0.406	0.113
Economically active males 25-34	0.595	0.034	0.610	0.028
Economically active males 35-54	0.861	0.130	0.855	0.105
Economically active females 25-34	0.684	0.088	0.671	0.071
Economically active females 35-54	0.734	0.087	0.735	0.068
Lone parents	-0.808	-0.133	-0.818	-0.108
Long term sick	-0.701	-0.180	-0.689	-0.141
One year migrants	-0.026	0.016	-0.037	0.010
Average number of rooms	0.567	0.051	0.568	0.040
Households per km^2	-0.451	-0.061	-0.484	-0.046
Agricultural employment	0.249	0.016	0.253	0.012

Table 9: Eigenvalues of principal factors of catchment area status

Factor	Eigenvalue	Proportion of variance	Eigenvalue	Proportion of variance
1	6.746	0.568	8.083	0.587
2	1.897	0.160	1.904	0.138
3	1.452	0.122	1.586	0.115
4	1.081	0.091	1.096	0.080
5	0.615	0.052	0.619	0.045
6	0.482	0.041	0.503	0.037
7	0.198	0.017	0.394	0.029
8	0.156	0.013	0.200	0.015
9	-	-	0.147	0.011

Table 10: Relationship between local tenancy group incomes

	Regional effects		Local Authority effects	
	Council tenants	HA tenants	Council tenants	HS tenants
Council tenants	-	-0.067 (0.047)	-	0.054 (0.091)
Housing association	-0.018 (0.012)	-	0.012 (0.020)	-
Owner occupiers	0.018 (0.018)	-0.035 (0.026)	-0.003 (0.026)	-0.002 (0.047)
Private renters	0.005 (0.011)	0.044 (0.027)	0.015 (0.017)	0.083* (0.050)
	Private rental		Private rental	
Owner occupiers	0.360** (0.064)		0.307** (0.064)	

Significant at *10% level, **0.1% level

Dependent variable is mean proportion in postcode sector reaching Key Stage 2 Level 4 and above.

Incomes are postcode sector mean incomes.

Standard errors adjusted for clustering on postcode sectors (5687).

All models include local authority dummy variables.

Models weighted by school size.

Instrument is average rooms per household in postcode sector, from 1991 census.

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