Valuing Primary Schools

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Executive Summary

Parents of young children are pre-occupied with getting their children into good primary schools. If you have children who are approaching primary school age, then conversation inevitably comes round to this topic. Politicians and the media discuss the issue frequently. Government policy has, at least in principle, made parental preference the key factor in primary school admissions. In practice, demand for places in schools that perform well outstrips the number of places available. Constraints on class sizes mean that it is no longer possible to increases school size to accommodate excess demand. As a result, places must be rationed on the basis of other criteria – most importantly residential proximity. One of the few ways parents can increase the chances of admission to school of their choice is to move as close as possible to it. Indeed, we know of lots of anecdotal evidence to suggest that parents *are* prepared to move to try to secure admission to a good school, and that they pay a high premium for this privilege.

Although widely recognised and researched in the US academic arena, this issue has received much less attention in Britain, despite the popular interest. This paper fills this gap. We measure the price premium attracted by observably better schools, using property price data from the Government Land Registry and primary school performance tables from the Department of Education and Skills. This sample gives us near-universal coverage of property transactions and school performance measures in England from 1996 to 1999.

Our approach is to estimate how property prices change from one neighbourhood to the next, and over time, as primary school performance changes. We can place a common-sense interpretation on the change in household expenditure on property that proximity to better schools generates: it is the value, in monetary terms, that a household places on improvements in school performance. This interpretation has a sound theoretical basis, and the technique has been used over many years for valuing environmental goods and the physical attributes of property.

Our main results show that households pay between 3.1 percent and 8.8 percent on property prices for each 10 percentage point improvement in the performance score of local primary schools. This score is the proportion of pupils attaining Level 4 and above in the age-11, Key Stage 2 tests, as appears in the publicly available school league tables. We believe that our estimates in the lower range understate the true premium because they are based on annual performance measures, whereas parents residential choice is based on long-run school quality. Our preferred estimates put the figure up at 8.8 percent for the South East and the

North of England, or 5.3 percent in the South West and West of England. A second empirical approach, which looks at differences between adjacent neighbourhoods on either side of Local Education Authority boundaries in the London area, gives us similar results – around 5.4 percent on London property prices for each 10 percentage point improvement. In terms of a monetary valuation, these figures suggest that the average household is willing to pay between £59 and £117 per pupil, per year, for an improvement in school standards which sustains a one percentage point improvement in the performance scores.

We note that a twenty five percentage point performance advantage in London and the South East has a capitalised value of about £37000 in year-2000 prices – roughly equivalent to the cost of a private-sector primary education for one child for eight years. In annual terms, the state-sector still works out cheaper: around £3000 in additional mortgage payments compared to over £6000 in prep-school fees.

This sensitivity of property prices to local school quality implies that there is back-door selection into better performing schools on the basis of family income. This is clearly inequitable, and a barrier to equality of opportunity. The outcome may also be inefficient and un-meritocratic, in that some pupils with the capacities to take advantage of better primary education are excluded on the basis of income or borrowing constraints. If these issues are of concern, then policy makers may need to consider whether residential proximity should take such an important role in school's over-subscription criteria.

Note on methodology: We would be foolish to suggest that *any* relationship between property prices and primary school performance measures willingness to pay for school quality. Causality may work in the other direction – schools in wealthier neighbourhoods get better results because of the economic and social advantages of their intake. At a broader geographical level, differences between Local Education Authority policy and funding may generate a link between school performance and property values, particularly if school expenditure is partly funded from property taxes. We devote a lot of attention to minimising the errors that arise from these kind of problems. Firstly, our estimates rely on differences in prices and school performance between neighbourhoods that are immediately adjacent. Secondly, we look at performance differences which we can attribute to permanent characteristics of the school – specifically church school status, and age-range. We argue that these historically determined characteristics do not change much over time and are not, unlike the basic test scores, subject to change in response to changes in the catchment area socio-economic composition.

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1. Introduction

Severe inequalities in the measured performance of English primary schools across geographical space mean that parents are clamouring to get their children into the best schools. Indeed, there is a lot of anecdotal evidence to suggest that parents are prepared to move house to try to secure admission to a good school, and that they are often prepared to pay a high premium on property prices. Stories of soaring house prices close to good schools are commonplace. We heard stories from Local Education Authority staff of complaints and appeals by families failing to gain admission to a school of their choice, despite having moved house specifically for that purpose. One anonymous interviewee spoke of an expectant mother calling for advice on which streets she should consider moving to in anticipation of her unborn child's primary education. Another family, known to one of the authors, recently sold a three bedroom Victorian terrace in north London for a much smaller semi-detached house just over a mile away. This move cost them around £140000. For what net gain? A 35% increase in the proportion of children at the local primary school reaching the target level in Key Stage 2 assessment tests. For sure, these moves may buy more than just better schools – good schools are typically in neighbourhoods that are better in other ways: lower crime rates, quieter neighbours, cleaner streets, better local amenities. But some component of any premium paid for a re-location from a bad-school neighbourhood to a good-school neighbourhood may well be attributable to the price of an improvement in school quality.

This phenomenon is widely recognised in the US, and several attempts have been made to quantify it (see Black, 1999, for references). For Britain, the issue has received much less attention in the academic arena, despite being discussed a great deal in the media, and amongst politicians and parents. The main aim of this paper is to start to fill this gap. We empirically measure the premium attracted by improvements in primary school quality in England, using property price data from the Land Registry and the Department of Education and Employment's (DfEE) school performance tables. This sample gives us near-universal coverage of property transactions and school performance measures in England from 1996 to 1999. The technique we use – valuation using hedonic property price models – is not new, but our particular approach is novel. Traditional hedonic property price models are plagued by problems of collinearity and model selection problems induced by the inclusion of an excess of highly correlated explanatory variables[1] in the property characteristics matrix. We side-step this issue by using instruments for primary school performance and by exploiting the co-variation in house prices and school performance within narrowly defined spatial groups, which reduces the need for a large set of covariates. Our kernel-based technique for removing spatial fixed effects allows us to test the sensitivity of our estimates to various choices over the radius of the spatial reference group. Furthermore, to our knowledge, this is the first paper to value *primary* school performance in England.

Other researchers have looked at the value house buyers attach to secondary schools in England. Rosenthal (2000) finds rather low elasticities of house prices with respect to school performance, comparable with the US work of Judd and Watts (1981).[2] Cheshire and Sheppard (1995) estimate the value of location within specific school catchment areas in Reading and Darlington. Leech and Campos (2000) do the same for Coventry. Neither study relates this to school performance measures.[3] Furthermore, none of these studies look at primary school performance. We suggest this may be more important generally: hedonic methods relying on spatial associations to link properties to schools may be poor for evaluating secondary school performance, except in special cases where catchment area boundaries are well defined and exclusive. Teenagers are a fairly mobile group and can travel long distances to school. Mobility between Local Education Authorities is high for children in secondary education. In contrast, primary age children typically attend schools which are within walking distance (at least in urban areas), and catchment areas can shrink down to just a few blocks for those in the highest demand.

Our focus on primary schools also has a sound empirical and theoretical basis. We would expect primary school performance to be the principal object of choice by parents seeking to improve the life chances of their offspring. For a start, there is evidence that attainments in the early years are positively correlated with later academic and economic success (Feinstein, 2000, Feinstein and Symons, 1999; Gregg and Machin, 2000). If gains made in the primary years reap rewards in terms of achievements at secondary school, then the payoff for the investment is higher if the investment is made early on in a child's life.

[1] Floor area and number of rooms, for example – see Atkinson and Crocker (1987).

[2] Haurin and Brasington (1996), however, find a 0.52% increase in price for a 1% increase in the proportion of 9th graders passing all sections of the 1990 proficiency test in Ohio.

[3] Their later report (Cheshire, Marlee and Sheppard, 1999) prices GCSE A-C pass rates at £343 per 1% improvement in Reading, £50 in Darlington, £57 in Nottingham, but only the coefficient for Reading is statistically significant.

What is more, investment in good primary education may be a pre-requisite of admission to selective secondary schools. Given the high fixed costs of moving house, a rational parent will make a once and for all locational choice when their first child enters the education system.

Our focus in this paper is therefore upon the associations between local house prices and primary school performance. We use highly disaggregated price and school data to explore this link using hedonic pricing models in a variety of different guises. The rest of the paper proceeds as follows. In Section 2 we outline a simple hedonic property valuation model we use to evaluate the price consumers are willing to pay for improved school performance. This section also discusses two critical issues that underpin our work, namely the extent to which location matters for admission to primary schools and whether parents actually do pick where to live as a means of school selection. Both of these issues are important for the identification questions involved in developing our empirical model. This is undertaken in Section 3 where we also discuss a number of econometric issues thrown up by our approach. Section 4 then moves on to discuss the data we use and, as the data comes from several sources, the matching procedures we adopt. Section 5 then presents the econometric estimates of our house price models. Section 6 concludes.

2. Models and Methods

2.1 A hedonic model of the demand for good schools

We use a standard hedonic property value framework to assess the implicit price of school performance. This framework has been employed frequently in the environmental, land and urban economics literature to price local environmental amenities (see Rosen, 1974, for the classic exposition, or Sheppard, 1999, for a modern survey). Individuals are assumed to have weakly separable preferences over a set of housing and location characteristics. A dwelling comprises a bundle of these attributes. Sellers and buyers with different incomes and different preferences over local school performance and other property characteristics are matched efficiently by the property market. This leads to an implicit price surface that traces out the locus of efficient transactions in price-characteristics space.

In this framework some property attributes are embodied in the building itself (*e.g.* type of dwelling, number of rooms) whilst others are to do with the spatial location of the building (*e.g.* proximity to employment opportunities, local amenities, and environmental quality). Other attributes can be described as quasi-locational, or endogenously locational, and as such are directly dependent on the characteristics of those living nearby, like the 'status' of the neighbourhood. The quality of local schools may be thought of as partly exogenously locational, to the extent that quantity and quality of school inputs (like expenditures, head leadership styles, teacher characteristics, or structure of the school building) are not determined by the characteristics of the neighbourhood. But school performance may also be endogenously locational, in the sense that the characteristics, especially the education and earnings, of those in the neighbourhood whose children attend the school will be likely to affect the school's academic performance (*e.g.* as measured by pupil test scores). This potential endogeneity does present a problem for empirical analysis. A causal link from school inputs to pupil achievement and a causal link from local family incomes to pupil achievement are observationally equivalent in terms of data on local incomes or house prices and pupil test results. Careful discussion, and model implementation based upon this, makes the identification of the demand for school characteristics an important part of our analysis.

We can start the modelling discussion with a simple stripped down model which assumes that school quality affects children's early educational outcomes, and that variation in school performance is not generated purely by spurious spatial clustering of children of similar innate abilities or clustering of families with similar resources. Early educational attainments lead, in turn, to higher final educational achievements or reflect directly enhanced skills that lead to greater successes in adult life.[4] For simplicity, assume that we can characterise the effects of primary school quality in terms of an impact on adult expected earnings or lifetime wealth. As such, primary school performance is a desirable commodity for parents, either because they are purely altruistic, or because they expect some form of payback from their children in their later years.

[4] Many studies show this to be the case. For example, Gregg and Machin (2000) show early test scores to be important determinants of educational success and that they have a link with adult labour market outcomes over and above educational qualifications. Dearden, Ferri and Meghir (2001) show the same over and above school characteristics.

To formalise this in a simple model, we write the preferences of owner-occupier households as a function of household consumption, average lifetime income of own children or young dependants, and characteristics of the property and its location. By lifetime income we mean the expected present value of lifetime income. This means we specify the following utility function:

$$U = U\left(c, \bar{y}^c, \mathbf{q}, \mathbf{l}\right) \tag{1}$$

where c is a numeraire composite consumption commodity, y^c is lifetime income of own children (the bar denoting an average), **q** is a vector of structural housing characteristics, **l** is a vector of locational characteristics. One can characterise the process of generation of lifetime income in terms of an educational production function, with state-sector school quality and a vector of other inputs. Of course, parents always have the option to transfer wealth directly to their children rather than allocate their resources to the inputs in the educational production function. This results in a production function of the form:

$$y^c = f(x, z) + y^t + y^s \tag{2}$$

where child income is related to local school quality x and other inputs into the human capital production function z, together with y^t which is direct transfers from parents and y^s, the contribution to the child's household income by any future spouse.

House prices are determined as a function of the same attributes, where the attributes are traded at a set of exogenous prices $\boldsymbol{\theta}$ fixed by demand and supply equilibrium at a broader geographical level:

$$P_h = P_h(x, \mathbf{q}, \mathbf{l}; \boldsymbol{\theta}) \tag{3}$$

The household lifetime budget constraint is:

$$y^h = c + P_h(x, \mathbf{q}, \mathbf{l}; \boldsymbol{\theta}) + P_z(z, k) + ky^t \tag{4}$$

where *k* is the number of children in the household and $P_z(z, k)$ is other expenditure on their human capital (*e.g.* on private education). Assuming the choice space is continuous so that households can purchase their optimum bundle we have the first order condition for *x*:

$$\frac{\partial U/\partial y^c \cdot \partial f/\partial x}{\partial U/\partial c} = \frac{\partial P_h}{\partial x} \qquad (5)$$

This is the standard condition that justifies the use of an estimated implicit price function $P_h(\cdot)$ in the estimate of the marginal willingness to pay for local amenities. Note that the option of transferring wealth directly to children implies a relationship between the implicit price of school quality and the returns to school quality in terms of an expected child's lifetime income.

$$\frac{\partial \bar{y}^c}{\partial x} = \frac{1}{k}\frac{\partial P_h}{\partial x} \qquad (6)$$

or

$$\frac{\partial \ln \bar{y}^c}{\partial x} = \frac{P_h}{k \cdot \bar{y}^c} \cdot \frac{\partial \ln P_h}{\partial x} \qquad (7)$$

Hence, given an appropriate specification of P_h and individual level data on house prices, neighbourhood school quality, housing attributes, and locational characteristics, it is possible to estimate the marginal willingness to pay for local school performance. In the case where school performance is valued purely as an input into the production of children's lifetime wealth, marginal willingness of parents to pay for x will be the marginal effect of the school performance measure on the present value of their children's total future earnings.

There are, however, some important issues to do with this specification that we need to explore further. In particular one needs to pay attention to the extent to which location matters for admission to primary schools and whether parents actually do pick where to live as a means of school selection. We discuss these issues next.

2.2 Does location matter for primary school admission?

Any attempt at valuation of schooling using the hedonic technique requires some method of linking property prices in a given area to the performance of schools available to residents in those properties. In our analysis there is an implicit assumption that geographical proximity to a school is an important criterion for admission. Whilst geographical proximity is one criterion, it is certainly not the only one. Local Education Authorities operate their own systems of prioritising applications to a primary school. Legal precedent (the Rotherham Judgement, 1997) has determined that parental preference must be the LEA's first consideration. However, good primary schools are usually oversubscribed, so the admissions authority must employ some system for ranking applications in order of priority. Typically, for LEA administered schools, priority is assigned according to the following oversubscription criteria:

1. those with siblings at the school

2. those with special educational or medical needs

3. those resident in a local "catchment" or "neighbourhood area"

4. children of those employed in the school

5. those ranked first by some other geographical criteria *e.g.* walking distance to the school.

However, the exact details and order vary from LEA to LEA. For religious schools, some statement or evidence of religious affiliation is usually the first criterion to be met. Even then, parents must attend the local church regularly, or the school must be the nearest of the same denomination for children to be eligible to attend. Neighbourhood or catchment areas may have been drawn out long ago and left unchanged (*e.g.* the London Borough of Brent), or may be re-drawn year on year in line with demand (*e.g.* Croydon), or only defined by maximum distance in the previous year's admissions (*e.g.* the London Borough of Hackney). Exclusion solely on the basis of residence outside a catchment area is illegal under English law, (at least since the Schools Standards and Framework Act 1998). Pupils cannot legally be excluded even if they live outside the school's LEA (the 1989 Greenwich Judgement). However, none of the LEAs we contacted drew their catchment or neighbourhood area boundaries to cross LEA boundaries. Consequently, children applying to oversubscribed schools from outside the LEA would only receive priority above children within the LEA and close to the school if they had siblings already at the school, or met other higher-ranked admissions criteria. Although catchment area boundary data might be helpful, we suggest that close proximity to a primary school is a reasonable proxy for meeting the geographical criteria for admission.[5]

What is clear, is that choosing a location within the LEA and close to the school will maximise the chances of school admission for a family moving house for this purpose, whatever other criteria have been met. It will also minimise the costs of delivering children to school. Since we are interested in the price premium generated by those actively seeking school quality, and since catchment areas are non-exclusive, we argue that the relationship between mean neighbourhood property prices and mean neighbourhood school performance will provide at least as much information as data based on individual schools and catchment areas. In this work, we use the association between property prices and primary school performance averaged at the postcode sector level – a spatial unit of around 2500 households. We also test this assumption by comparison with fixed effect models that rely on property price and school performance differences between adjacent postcode sectors separated by Local Education Authority boundaries.

2.3 Do parents really care?

Word of mouth is one thing, but is there any other qualitative evidence that parents use locational choice as method of school selection? The Survey of English Housing provides clear evidence that neighbourhood is an object of choice by homeowners, particularly those with children. Unfortunately, schooling is not one of the reasons on the list of responses available to respondents. However, in the 1997/8 wave of the survey, 29% of 2674 owner-occupier respondents with children gave "to move to a better neighbourhood" as their first reason for their last move, and 33% included it somewhere in their list of reasons.[6] For those without children, the figure was 18% as a first choice, 21% as a reason.[7] Including "other personal or family reasons" as a category that embraces school choice decisions puts the

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[5] The London Borough of Hackney publishes information on the maximum distance of residence for successful applicants in the previous year. The median distance in 1999/2000 amongst 27 schools was 580m. Weighting by the difference between applications and intake gives a demand-adjusted median of 450m.

[6] It also appears to be the case that concern over neighbourhood is an increasing phenomenon. In 1993/4 only 13% of home owners with children gave neighbourhood as their first reason for moving, compared to 7% for those without children.

[7] Tests of independence convincingly reject the null that this decision is unrelated to family status: $\chi^2(1) = 44.0$.

figure at 44% for homeowners with children. The survey also asks what the respondents think of local schools. Of those with children, 47% believe the schools are "very good" and another 42% that schools are "quite good". Interestingly, 54% of those with children who moved for neighbourhood reasons believe that local schools are "very good", compared to 45% of those with children who did not move for neighbourhood reasons.[8] Whilst this only weak evidence that education is the main concern in a family's choice of neighbourhood, schools must surely score highly in any list of neighbourhood attributes ranked by desirability to families with children.

3. The Empirical Approach

3.1 Empirical model

We do not have individual-level house price data. Instead, in the Land Registry data set we use, annual housing transactions are aggregated to provide an average of prices in four property-type categories (flat/maisonette, detached, semi-detached, or terraced only) at postcode sector level. We adopt postcode sector as our geographical neighbourhood unit of analysis. The sample of transactions on a house of type r in a given postcode sector will contain a mix of structural characteristics $\mathbf{q}$ (number of rooms, for example). Assuming that the sample value of the price of houses of type r in postcode sector i at time t with mean characteristics $\overline{\mathbf{q}}$ *is* the market price of a house of type r in neighbourhood i at time t, with characteristics $\overline{\mathbf{q}}$, then the household hedonic price function can be represented by a hedonic price function at the neighbourhood-house-type level. Alternatively, think of the mean postcode sector house price as the price of a representative house of type r in that neighbourhood.[9]

[8] The test of independence gives $\chi^2(1) = 9.4$, with an associated p-value of 0.002.

[9] We have no detailed information on structural characteristics for our sample of house transactions. One option would be to proxy the characteristics with Census data on owner occupied housing in 1991. Unfortunately, the only Census variables which could reasonably be treated as exogenous (i.e. not subject to change in response to shifts in residential composition) are those that give the distribution of rooms across households in the postcode sector. As this will be a noisy measure of the property characteristics, because transactions take place on only a small subset of local properties, and because we have no separate measure for each property type we therefore prefer to subsume $\overline{\mathbf{q}}$ in our specification of the effect of location.

The choice of functional form for the hedonic price function has been an issue of some debate. Popular choices include log-log, linear, box-cox transform, or semi-log functions. Here, we assume a linear, semi-log functional form, with an unknown function $g(\mathbf{l}_i, t)$ mapping locational characteristics to house price in each time period. We present some semi-parametric evidence that the log-linear specification is acceptable. This imposes the constraint of a constant percentage response in house prices to a one percentage point absolute increase in school performance. Our specification of the log-price of a house of type r in neighbourhood i at time t is then:

$$\ln P_{irt} = \alpha + \beta_x x_{it} + g(\mathbf{l}_i, t) + h_r + u_{irt} \tag{8}$$

where h_r are fixed effects distinguishing the four house types.

3.2 Estimation strategy

Estimation of a full structural specification of the mapping of neighbourhood characteristics $\mathbf{l}$ to house prices would require data on local amenities, local housing characteristics, the proximity of neighbourhoods to transport services, local labour demand, environmental quality and other unknown local goods. The general function $g(\mathbf{l}_i, t)$ could then be replaced by a specific function. In the absence of this data and any prior knowledge about exactly what should be included, we must replace the mapping of $\mathbf{l}$ to house prices with some specification that maps neighbourhood to house prices through the location of the neighbourhood in geographical space and time. The problem could be avoided by specifying $g(\mathbf{l}_i, t)$ as a spatial fixed effect at the postcode sector level (constant over time) with separate time effects. A clear problem with this approach is that the school performance measures are bounded by [0,1], so the schools at the top initially will show little or no improvement over time. To retain some cross-sectional variation, we must therefore specify area fixed effects corresponding to a wider geographical space which encompasses neighbourhood *i*. Obviously, if the effects of location and local amenities are uncorrelated with the other independent variables, we could get consistent estimates using ordinary or generalised least squares.

A drawback of the area fixed effect approach is that it requires some arbitrary specification of the comparison neighbourhood group. Here, we can exploit the hierarchical structure of the postcode to define spatial groups. Our observations at the postcode sector level are nested within groups at the postcode district level (obtained by deleting the final digit from the sector postcode). Districts are nested within postcode areas, designated by the first one or two characters of the postcode. Unfortunately, there is no guarantee that the postcode districts are relatively homogenous in their neighbourhood characteristics, or that they are representative of the neighbourhood at the postcode sector level. Boundary postcode sectors may be poorly represented by the postcode district in which they fall. Postcode district may also be too large a geographical grouping (around 13000 households) to be effective as comparison groups. Using noisy measures of locational fixed effects will therefore lead to inconsistent estimates of the model parameters.

An alternative approach, which we adopt here, is to infer the mapping of location to house price non-parametrically and use this information to replace the function $g(\mathbf{l}_i,t)$. The problem of arbitrary spatial aggregation can be partly overcome by estimating the locational effect on house prices in a neighbourhood as a weighted average of its own characteristics and those of the surrounding neighbourhoods in the sample. This is fairly easily done using a kernel regression procedure, whereby Cartesian co-ordinates are employed to measure the spatial location of an observation and the weights that should be applied to other observations. Observations in closer proximity receive the highest weights. It is still necessary to specify what we mean by 'nearby' observations. This amounts to deciding on a bandwidth b for the kernel, which determines how rapidly the weights decrease as we move away in space from a given observation.

We allow time effects via a separate non-parametric surface for each period, so we have:

$$g(\mathbf{l}_i,t)=\sum_t d_t \cdot g_t(\mathbf{l}_i) \tag{9}$$

where d_t is a time dummy. This allows for differential growth in house prices across geographical space.

Our *smooth spatial effects* estimator is an application of the partial linear model – see, for example, Robinson (1988), Hardle (1990) or Stock (1991). Expressing the model in deviation from estimated expected values, given the spatial location, *c1*, *c2* and the choice of bandwidth b for the comparison group:

$$[\ln P_{irt} - m(\ln P_{irt} \mid \mathbf{c}, b)] = \beta[x_{it} - m(x_{it} \mid \mathbf{c}, b)] + \boldsymbol{\gamma}'[\mathbf{z}_{irt} - m(\mathbf{z}_{irt} \mid \mathbf{c}, b)] + \varpi_{irt} \tag{10}$$

The locational mean of a variable y, $m(y \mid c, b)$ is estimated by the bivariate Nadaraya-Watson estimator

$$m(y \mid \mathbf{c}, \rho) = \frac{\sum_i^N y \times k\left\{(\mathbf{c} - \mathbf{c}_i)' \mathrm{B}^{-1} (\mathbf{c} - \mathbf{c}_i)\right\}}{\sum_i^N k\left\{(\mathbf{c} - \mathbf{c}_i)' \mathrm{B}^{-1} (\mathbf{c} - \mathbf{c}_i)\right\}} \tag{11}$$

where B is a 2 x 2 bandwidth matrix, *e.g.* $b^2 \times \mathbf{I}_2$, and $k\{\cdot\}$ is a multivariate kernel. For the Gaussian kernel this is $k\{\mathbf{v}\} = 2\pi^{-1} \exp\{-0.5\mathbf{v}\}$[10]. Parameters β, γ and their variance covariance matrix can then be estimated by ordinary least squares on the transformed variables.

3.3 Bandwidth choice

The choice of bandwidth is important as we have no way of knowing, other than by casual empiricism, what geographical area comprises the correct reference group. We therefore experimented with a number of choices of b. A bandwidth of near zero would be approximately equivalent to a fixed effects estimator with postcode sector fixed effects. In this case, the relationship between school performance and house prices can be identified by changes over time, but only if we impose further restrictions on $g(\mathbf{l}_i, t)$.[11]

Note also that the land area and household density of postcode sectors is far from constant. Postcode sectors, districts and areas in rural locations are much larger than in urban locations, reflecting lower population densities in rural locations. To compensate for this, we

[10] For details of multivariate kernels, see Silverman (1986)

[11] For example, we might impose $g(\mathbf{l}_i, t) = f_t + g(\mathbf{l}_i)$ so that g depends on general time effects and $g(\mathbf{l}_i)$ is estimated by postcode sector dummies, or a near zero bandwidth. However, as discussed above, this is probably a bad choice as it relies on the time-series variation only, and because it constrains property price growth to be equal in all areas. At the other extreme, an infinite bandwidth is equivalent to the OLS estimator, with the function $g(\mathbf{l}_i)$ estimating a constant.

weight our bandwidths in inverse proportion to the square root of the local household density as recorded in the 1991 census. Our main results use a bandwidth corresponding to approximately 3400 households. This bandwidth choice process is discussed in some more detail in Appendix A.

3.4 Potential endogeneity of school performance

As we have already noted, school performance is likely to be related to local house prices through factors other than sorting by parents on good schools. A relationship between neighbourhood incomes and school performance could arise through differences in Local Education Authority funding or policy across areas. At a more localised level, differences are generated by heterogeneity in family and community inputs. High income, highly educated and highly motivated parents have more resources to devote to their child's education outside of school and promote high educational attainments in their children. Children in these families may also benefit from positive spillovers from similarly affluent and motivated neighbours both in and out of school. On the other hand, children from low income families in deprived neighbourhoods may find little parental support for their education, and be de-motivated by their peers, neighbours and environment. These differences will be exacerbated by heterogeneity in inherited academic abilities across income groups.

Highly localised exogenous variation in the quality and type of housing stock and in the supply of environmental goods will lead to a measured within-spatial-group correlation between house prices and school performance. This reflects the effect of family and neighbourhood incomes on school performance, not the effect of school performance on local house prices. Two schools, equivalent in terms of their funding, their teaching techniques and staff abilities, but located in contrasting micro-neighbourhoods, will differ in performance due to differences in the families of the children that attend them. Correlation between school performance and local house prices is induced by demand for other housing and environmental goods, coupled with a causal link from family incomes to attainments.

This can be represented as a standard simultaneous equations model:

$$\tilde{y}_i = \beta \tilde{x}_i + \tilde{\varepsilon}_i \qquad (12)$$

$$\tilde{x}_i = \gamma\tilde{y}_i + \tilde{\omega}_i \tag{13}$$

where $\tilde{y}_i$ is a measure of average local average incomes or housing expenditures, $\tilde{x}_i$ is local school performance, and the variables are in deviations from spatial group means. The probability limit of the OLS estimate of β will be:

$$\text{plim}\,\hat{\beta} = \beta + \left(\gamma^{-1} - \beta\right)\cdot\left(\frac{\sigma_\varepsilon^2}{\gamma^{-2}\sigma_\omega^2 + \sigma_\varepsilon^2}\right) \tag{14}$$

Hence, OLS will be inconsistent in an upward (if $\gamma\beta < 1$) or downward (if $\gamma\beta > 1$) direction. We can identify equation (12) if we assume a recursive dynamic structure. Adding time subscripts to (13) and (14) gives:

$$\tilde{y}_{it} = \beta\tilde{x}_{it-1} + \tilde{\varepsilon}_{it} \tag{15}$$

$$\tilde{x}_{it-1} = \gamma\tilde{y}_{it-1} + \tilde{\omega}_{it-1} \tag{16}$$

This implies that this year's house prices respond to last year's school performance, which is unaffected by current house prices. Ordinary least squares applied to the deviations of the variables from local spatial group means gives consistent estimates of β, but only if the within-group transformation removes all correlation between $\tilde{\varepsilon}_{it}$ and $\tilde{\omega}_{it}$, and serial correlation in $\tilde{\varepsilon}_{it}$.

3.5 Transitory and permanent school performance

A drawback of the model in (15) is the implausibility of the assumption that parents move house on the basis of single year measures of school performance. The fixed costs associated with housing transactions and family relocations would make moves each year in response to league tables highly inefficient. Instead, parents are likely to look to longer run indicators of school performance. They may seek further information from school visits, OFSTED reports, teaching staff, and by talking to other parents. Results published in the national tables are noisy measures of long-run school quality, and parents are more likely to seek out schools with proven track records of high performance, or those which exhibit characteristics that are, on average, associated with good long run performance.

On this basis, least squares estimation of (15) will lead to a downward biased estimate of β interpreted as the marginal effect of long-run anticipated school performance on house prices. This is simply an application of the classical measurement error model. If permanent school performance is functionally dependent on observable neighbourhood characteristics, such as the proportion of local authority tenants in the catchment area, then inclusion of this neighbourhood characteristic in the OLS regression will further downward bias the estimate of β. We may also infer a relationship between house prices and the included neighbourhood characteristic even where there is no direct structural relationship. See Appendix B for details.

If parents are really interested in long run school performance, a better specification of the influence on property prices is:

$$\tilde{y}_{it} = \beta \frac{1}{k} \sum_{t-k}^{t-1} \tilde{x}_{is} + \tilde{\varepsilon}_{it} \tag{17}$$

The mean over time provides more information about permanent components of performance than a single year measure. Here however, we lose k periods of property price data. In a short panel, the time average of school performance may still be an inadequate indicator of school reputation.

3.6 Identification through instrumental variables

As discussed above, the simultaneity of sorting by incomes on school performance and the effect of incomes on school performance, the transitory nature of yearly school performance measures and the dependence of school performance on more permanent exogenous neighbourhood characteristics lead to inconsistent OLS estimates. The direction and magnitude cannot be determined *a priori* without further assumptions. What is more, this problem cannot be overcome by comparing within narrower spatial groups. Firstly, less variation in school performance within spatial groups will exacerbate the transitory performance problem. Secondly, no spatial grouping which encompasses more than one catchment area can guarantee to remove unobserved differences in neighbourhood within groups. Better data can partly overcome this problem. Black (1999) compares neighbouring properties on either side of catchment area boundaries to eliminate neighbourhood differences, but this approach requires household level data and well-defined catchment area boundaries. Even a fixed effect estimator which exploits variation over time within catchment areas can not differentiate between the effects of exogenous changes in house prices over time (and hence resident's incomes) on school performance and the effect of exogenous changes in school performance on house prices, without the additional assumption of recursivity expressed in (15).

But consistent estimates can be obtained under both conditions – the endogeneity of school performance and the use of transitory performance measures – using an instrumental-variables procedure, assuming we can find suitable instruments. Detailed school and teacher characteristics instruments – head teacher's leadership styles, teacher skills – are potential instruments, but these are not readily available at school level. Even these characteristics are endogenous to the extent that good teachers and heads can pick and choose the schools at which they work, due to their bargaining advantage in the labour market for teachers. Teachers with the best observable characteristics will probably select themselves into those schools that are in the best neighbourhoods and have the highest performance advantage in terms of catchment areas. Other school investments such as expenditure per pupil and pupil teacher ratios, which are commonly used in the analysis of school performance, show little variation within LEAs. These are not useful here, where we need variation across only a few postcode sectors. In any case, the jury is out on whether the variation that exists in these inputs has any measurable impact on performance (see Hanushek (1996), Card and Krueger (1996) for reviews).[12]

Instead, we draw on the very limited set of characteristics available in the school performance tables. As instruments for primary school performance, we utilise historically determined school characteristics, namely an indicator of "Community" funding and admissions status, and indicators of the school's age range. Both, we assume, reflect organisational differences which impact on Key Stage 2 performance. Community schools

[12] We tried qualified teacher-pupil ratios as an instrument at school level, but the underlying relationship between school performance does not work in the direction that we, and we assume parents, would expect. This suggests that more teachers are assigned to bad schools or disadvantaged areas, or that classes are smaller in schools that are less in demand. Either case invalidates its use as an instrument.

are LEA funded and operated schools, rather than voluntary aided or voluntary controlled schools (which are generally religious). It is generally recognised - and borne out by the data - that religious schools perform better than Community schools. Anecdotally, it is common for parents to rediscover their lost faith and attend church in the year prior to their child's admission year! Differences in school performance across the age range of the pupils will reflect factors such as continuity between primary and junior teaching, starting age of formal education, school size and allocation of resources to Key Stage 2 tests.

We maintain the assumption that variation in these characteristics is not determined by variation in local incomes – once we control for variation at a slightly broader spatial level – and does not drive variation in house prices other than through its relationship with school performance.[13] This assumption is likely to break down if the spatial grouping is too wide, because school funding status may depend on Local Education Authority policy. It is also plausible that funding status is influenced by neighbourhood characteristics, in particular by proximity to high density social housing. Local authority strategic planning means that Community schools are more likely to be located near local authority housing estates. Regressing the proportion of community schools in a postcode sector on the proportion of social housing, within postcode sectors, we obtain a coefficient of 0.132 (with an associated standard error of 0.043). A school in a postcode sector with 15% more local authority housing than average (the 95th percentile, and about one standard deviation) is about 2% more likely to be Community than Voluntary Aided or Voluntary Controlled. This would not be a problem for our house price models, except that educational status of a neighbourhood will itself be an object of selection by owner occupiers, so that proximity to social housing itself suppresses house prices. We test the robustness of our IV estimates to the presence of unobserved neighbourhood characteristics by the usual Sargan test of exogeneity. Correlation between funding status and social housing will invalidate our instruments if social housing density is unobserved, so we include a measure of the proportion of households who are local authority and housing association tenants, taken from the 1991 Census.

We use our instruments as deviations from their non-parametrically estimated local means. To summarise, our smooth spatial effects IV estimator is:

[13] Nationally, the proportion of religious schools is more than double the proportion of the family age population who profess to being practising, church-going, main-denomination Christians (Source: British Social Attitudes Survey).

$$\hat{\beta}^{iv} = \left[\tilde{\mathbf{X}}'\tilde{\mathbf{W}}\left(\tilde{\mathbf{W}}'\Omega\tilde{\mathbf{W}}\right)^{-1}\tilde{\mathbf{W}}'\tilde{\mathbf{X}}\right]^{-1}\tilde{\mathbf{X}}'\tilde{\mathbf{W}}\left(\tilde{\mathbf{W}}'\Omega\tilde{\mathbf{W}}\right)^{-1}\tilde{\mathbf{W}}'\tilde{\mathbf{p}} \tag{18}$$

where $\mathbf{X}$ is the regressor matrix, $\mathbf{W}$ is the instrument matrix and $\mathbf{p}$ the house-price vector. The tilde indicates deviations from the non-parametric estimates of the group means in the smooth spatial effect models. In the smooth spatial effect models, $\tilde{\mathbf{W}}'\Omega\tilde{\mathbf{W}}$ is estimated using the Huber-White method, with clustering on postcode sectors. Our estimated standard errors are, similarly, adjusted for clustering on postcode sectors to allow for the fact that we have multiple schools, house types and time periods in each postcode sector/district, so unobservables are correlated within these groups.

3.7 Identification from differencing across local authority boundaries

If we had data on catchment area boundaries we could do better in assigning property prices to schools.[14] Without this information, our estimates on the price-performance response based on matching mean postcode sector prices to mean postcode sector school performance may be lower bounds, due to the classical errors-in-variables problem. The mean school performance in a postcode sector is a noisy measure of the mean school performance of the schools available to residents of that postcode sector. The task of mapping catchment area boundaries to a national sample of primary schools is a formidable one, which we leave others to undertake. Instead, to check whether absence of catchment area information presents a serious challenge to the credibility of our estimates, we have considered a subset of postcode sectors in the Greater London area and infer catchment area boundaries. We do this on the assumption that any Local Education Authority boundary is also a primary school catchment area boundary. As discussed in the introduction, defined catchment areas do not generally cross LEA boundaries, though applicants from outside the LEA are often not excluded. This model is similar to that used in Black (1999) and relates to Leech and Campos (2000), though both use detailed information on catchment area boundaries and property level data for a small geographic area.

[14] One solution to improving the match between schools and property prices is to average individual school performance within a given radius of the centroid of each postcode sector. Our initial estimates based on this approach were similar to those obtained by simple postcode sector matching. However, this procedure introduces an additional bandwidth selection problem, so was abandoned.

In this context the empirical model is as in equation (8):

$$\ln P_{irt} = \alpha + \beta_x x_{it} + g(\mathbf{l}_i, t) + h_r + u_{irt} \tag{19}$$

We now use a sample of postcode sectors that share Local Education Authority boundaries. The function $g(\mathbf{l}_i, t)$ is replaced by dummy variables indicating pairs of postcode sectors that are adjacent, but on either side of an LEA boundary, plus LEA dummies and time dummies or time-LEA interactions. Estimation of β relies on cross-LEA boundary differences in property prices and school performance, assuming that the immediately adjacent postcode sectors are from neighbourhoods which do not differ in ways which affect school performance. Adjacent postcode sectors which adjoin LEA boundaries but which are separated by some major physical obstacle are excluded, because the assumption that they form homogenous neighbourhoods is likely to be violated. This includes, for example, all postcode sectors separated by the Thames downstream of Richmond. LEA dummies remove differences in local council tax, housing and education policy. Unitary Authorities responsible for other aspects of local government are geographically coincident with LEAs in the London area.

4. The Data Set

4.1 Data description

The data set we use in this study comes from four sources, which we splice together at postcode sector level. Our house price data for England and Wales is from the Government Land Registry. Our primary school performance data comes from the public primary school performance tables, available from the Department of Education and Employment. Additional data (on the proportion in social housing, household density and postcode sector grid references) is derived from the 1991 Census for England and Wales. Fuller details are available in Appendix C. We end up with an unbalanced panel with up to four property types and property prices in each postcode sector in each year. Each postcode sector has a single school performance measure in each year. Household density, grid-references and the proportion in social housing vary across postcode sectors but are constant across years in our data.

In all, 7444 postcode sectors and 2060 postcode districts are represented in our matched house-price and primary-school sample for the years 1996 and 1999. The mean number of households is 2900 per sector, and 12900 per district. In this sample, there are primary schools in 5681 sectors and 1888 districts. The mean number of sectors per district is 5 in the total population of postcodes, 4.66 in our house-price-school sample, 3.81 in the primary school sub-sample. In the performance tables there are 14490 primary schools in 6276 postcode sectors but only 11832 in 5850 postcode sectors have confirmed Key Stage 2 results. Problems in matching the data means we have lost only 3% of the primary schools with Key Stage 2 information (some because we have no corresponding house price data; the rest are lost due to their being no corresponding postcode sector in our census look up tables). Postcode sectors for which we have house prices, but no school information (either because there is no school present here, or because there was no successful match between house-prices and schools) are assigned zeros Key Stage 2 results. We include a dummy variable to indicate these postcode sectors in our regressions.

Figure 1 illustrates the geographical relationship between postcode sectors, districts and primary schools. It shows one postcode district – E3 in the East End of London. This district, being an inner city area, has a higher density of housing and primary schools than average, but it illustrates the main features used in the analysis. The housing density in sector E3 4 is 6000/km^2, so a bandwidth choice of 3400 households in our smooth spatial fixed effect estimator corresponds to a radius of 0.42km. Very little weight will be attached to sectors beyond 2.5 bandwidths, so the spatial group for a given postcode sector, assuming a bandwidth of 3400 households is, roughly speaking, those postcode sectors whose centre is captured within a 1 km radius from the centre of the observation postcode sector. Each grid represents 0.5 km on this map.

The symbols in Figure 1 represent the school types. Black circles are community schools with nursery, reception, primary and junior years. White circles are junior-only community schools. The grey circle is a community school which apparently takes children from compulsory school age (5 years) only. Black triangles are Voluntary Aided (C of E and Catholic) primary schools. In this example of an inner city postcode district we can see a considerable variety of school types and age range within quite localised areas.

4.2 Descriptive statistics

We present our results separately for three broad geographical areas. These areas correspond to grouped Standard Statistical Regions. The grouping scheme was chosen to illustrate any broad regional differences in property markets, whilst retaining a mix of rural, urban and metropolitan areas within each area. The groupings we use are:

South East and East: London, South East and East Anglia

The North: East Midlands, Yorkshire and Humberside, North, North West[15]

West and South West: West Midlands, South West

The upper panel of Table 1 reports summary statistics on our postcode sector property price data set. House price observers may note that house price growth from 1998 to 1999 appears lower than we might have expected, considering the recent media attention on soaring house prices in the South East. Our figures show a growth of just over 11% in postcode sector mean house prices in the East and South East, between 1998 and 1999. This is less than the 14% growth between 1997 and 1998. Land registry published figures suggest a growth of over 15% in the South East. The anomaly is in part due to our use of annual averages, rather than the growth from the last quarter of 1998 to the last quarter of 1999 on which the land registry figure is based. Also, our sample includes only those properties with recorded postcodes. Some comparison with other data sources reveals that this sub-sample probably under represents higher price properties in 1997 and 1996.[16]

The lower panel of Table 1 shows some summary statistics for our postcode sector level school performance data. The performance measures are fairly similar in each regional

[15] It is arguable whether East Midlands should be included in the North, or in one of the other groups. Experiments with moving the East Midlands to other groups made little difference to the results. In a within-postcode district regression of log house prices on Key Stage 2 performance, moving the East Midlands in or out of any group does not change the estimated response parameter by more than one standard error.

[16] This seems to be the case when our sub-sample is compared with the full sample used by the Land Registry, or the random 5% sample conducted by the Society of Mortgage Lenders. It appears the postcode sector data under represents higher priced detached houses and flats in all regions. A probable explanation of this is that it under represents new high-end properties. The Land Registry confirmed that many new properties are registered without postcodes, so are missing from the postcode sector level data. The under-representation of these groups in the dependent variable has the potential to downward bias our regression estimates. Given that the difference between the means in the postcode sample and the full sample is only around 5% we do not expect this to be a serious problem.

group in each year, though The North is always marginally below the other areas. Attainment at Key Stage 2 has improved since the introduction of the performance tables in 1996, though there was little change between 1997 and 1998.

School characteristics are also given in Table 1 (those recorded in 1999). Key differences here are that the East and South East has slightly larger schools, the North has more schools with pre-school and reception years than other areas, and the West and South West has more voluntary aided or controlled schools and fewer junior schools. Variation in the age range across areas is attributable to LEA policy – in some LEAs, primary schools take children from compulsory school age only. In others, primary schools take children from age 4, or even earlier if a nursery is attached to the school.

Figure 2 displays the postcode district means of the proportion reaching Key Stage 2 Level 4 in 1999. It illustrates the geographical distribution of school performance in England. Each circle represents the centre of a postcode district, and its diameter is proportional to the mean local school performance. Variation between postcode districts accounts for 32% of the variance in measured school level performance, and 45% of the variation across postcode sectors. By contrast we can attribute nearly 80% of the variance in postcode sector mean house prices to differences between postcode districts.

The relative variation in school performance across time and geographical space tells us something about the usefulness of exploiting time-series variation in our estimates. Taking the sub-sample of postcode sectors with primary schools for 1996 and 1999 we find that 75% of the variation in school performance can be explained by postcode sector fixed effects. Regressing out postcode sector fixed effects and general time effects, the residual variance is 0.00278, against overall variance of 0.0248. Only 11% of the initial variance is between-group (i.e. across postcode sector variation). What is more, if we look at log property prices in the same sub-sample, we find that 95% of the variance is attributable to postcode sector fixed effects. The residual variance is only 2.5% of the raw variance in log house prices! Clearly, the differences between postcode sectors in house-price time trends are small relative to other source of variation.

It is also informative to look at how changes over time in school performance are related to initial performance in 1996. Our intuition is that growth will be less in the postcode sectors with better performing schools in the first period, as it must be at the very top: this is indeed the case. The Table in the text below shows the change in absolute percentage terms for all postcode sectors, between 1996 and 1999, by quintile of performance in 1996. There is a strong downward trend in performance growth as we move up the initial performance distribution. It is pretty clear from the fact that changes in school performance are negatively related to school performance, and because there is so little between group variation in our data, that variation over time is unlikely to be helpful in identifying the response of house prices to school performance.

	Bottom Quintile	2nd Quintile	3rd Quintile	4th Quintile	Top Quintile
Change in Key Stage 2 Performance, 1996-99	0.235	0.184	0.146	0.111	0.059

The correlation between house prices and school performance is illustrated in Figure 3 which tests our log-linear specification semi-parametrically using a kernel regression of the deviations of 1999 log house prices from postcode district means on the deviation of average 1996-1998 school performance from postcode district means. The relationship shows an upward sloping relationship between house prices and Key Stage 2 performance, and looks comfortably linear for all regions.[17]

5. Results

5.1 Baseline results

A set of baseline results are reported in Tables 2a, 2b and 2c for the South East and East, the North and West and South West area configurations discussed earlier. Each Table reports four specifications of log-linear regressions of property prices on school performance, with smooth spatial fixed effects. The estimates are regressions on the deviations from the local spatial group means, where these are estimated non-parametrically for each period. The minimum, mean and maximum bandwidths are shown in the table notes. The distribution of household density on which the bandwidth is based is right skewed, so the median bandwidth is around 1km. An illustration of the function $g(\mathbf{l}_i, t)$ that defines the smooth spatial fixed effects surface is given in Figure 4, for the London region.

[17] This is a semi-parametric representation of the recursive, mean-performance model in equation (17).

Column 1 of Tables 2a-2c uses the school's Key Stage 2 performance un-instrumented, with no controls other than a property type indicator (and the spatial fixed effects). Column 2 is identical to 1, but regresses 1999 property prices on 1996-1998 mean Key Stage 2 performance. Column 3 instruments school performance by school type and age range dummies. Columns 4 to 6 then include the proportion of tenants in social housing in the postcode sector as an additional regressor.[18] A common pattern of results appears across all three regional groupings. In all cases there is a positive statistically significant association between house prices and school performance. Within tables, there are differences between the magnitude of the estimated associations for the four specifications presented, but the differences look very similar when viewed across Tables 2a, 2b and 2c.

The un-instrumented estimates of the implicit price of Key Stage 2 performance are very close across regions. In all three Tables inclusion of the social housing area attenuates the OLS estimate of the implicit price of Key Stage 2 by between 33% and 40%. Calculation of the minimum distance estimate of the OLS parameter, based on the separate regional regressions in column 3, shows it to be 0.305 and we do not reject equality of the parameters across regions (*p*-value = 0.215). This implies that a 10% increase in the mean Key Stage 2 performance in a postcode sector is associated with a 3% premium on property prices. In the London and South East this is equivalent to a premium of about £3683 in 1999.

The second and fifth columns of Tables 2a-2c show SSE models for 1999 property prices, using 1996-1998 mean school performance. This is the model of equation (17). Without social housing included as a local control, the 3-year averages give estimates which are up to 48% higher than the OLS estimates using yearly measures. Once we control for social housing, the gap increases by up to 64%. We therefore conjecture that the 3-year means are better measures of long-run performance than the raw year to year results, and that the annual measures give downward biased estimates. The degree of downward bias is sensitive to the inclusion of social housing as a control, because this is in itself a good proxy for long-run school performance. The minimum distance estimate based on 3-year means,

[18] Note we do not report results looking at secondary school performance. This is mainly because we feel that we cannot do a good enough job on matching schools to postcode sectors. Indeed this is borne out to the extent that our results suggested primary school performance to be the dominant schooling based factor in localised house price determination: OLS estimates and t-statistics for primary school performance elasticities are six times higher than those obtained for GCSE pass rates. Once we instrument school performance, the secondary performance elasticities and t-statistics are driven to near-zero, whilst the primary school response more than doubles. Our estimation technique effectively removes secondary school effects, where catchment extends over a much wider geographical area.

conditional on social housing, is 0.411 and we do not reject equality across regions (*p*-value = 0.972).

The Instrumental Variables estimates in columns 3 and 6 are, however, even higher still. Let us first consider the suitability of our instruments. We use age range and school type indicators as instruments for Key Stage 2 performance. To show that our instruments are strongly correlated with school performance, we ran the underlying prediction regressions. These are given in the table in Appendix D which reports within-postcode-district regressions of postcode sector mean Key Stage 2 results on the proportion of community schools, the proportion of schools in each of two age ranges, plus all the exogenous variables in the property price equation. The Table shows the estimated coefficients on the variables excluded from the property price equation, and the F-tests for their exclusion (adjusted to compensate for multiple observations per postcode sector). The estimates show a broadly similar pattern across regions, and the F-statistics and t-statistics are always high. The proportion of children at community schools achieving Level 4 is between 4.7% and 6.9% lower than those at voluntary aided or controlled schools.[19] [20] [21]

[19] As discussed above Neal (1997) finds that the advantage of a catholic secondary education in the US varies by geographical location. He finds that it is only in urban areas that catholic schooling offers clear benefits. If this were true in our sample, we would have to question the usefulness of community/voluntary status as an instrument, without area interaction effects. We investigated whether religious school advantage we detect here varies by area, but found no clear pattern. In London, the religious school advantage rises to around 12.3% (s.e. 1.04%), but it is similar or even higher in some, predominantly rural postcode areas, for example Peterborough (13.5%, s.e. 4.1%) or Carlisle (11.3% s.e. 5.8%), and lower in other urban areas such as Manchester (7.0% s.e. 3.5%). Unfortunately, Neal's analysis of the impact of catholic schooling sheds little light on the endogeneity of religious status with respect to neighbourhood status, as he disregards sorting by parents on school quality.

[20] School type will not be a valid instrument if it picks up differences in the ethnic mix of the neighbourhood. If religious schools exclude children from ethnic groups whose family incomes are on average lower than those of the families of children who meet the admissions criteria, and families from the higher income group move close to schools which admit their religious denomination, then the school type indicator may pick up a family income effect on school attainments not a difference in school inputs. In practice, ethnicity has little overall effect on school performance except in the South East, and we find that inclusion of ethnic controls in the regressions has little impact on the results. To check whether ethnic composition affects our results, we carried out within-postcode district regressions of school type on the post-code sector proportion from Afro-Caribbean and Indian subcontinent ethnic groups. The coefficient on either ethnic group is always close to zero with a p-value greater than 50% for the North, West and South West regions. For the East and South East we cannot reject the hypothesis that the proportion of community schools is positively related to the proportion of residents from the Indian sub-continent groups. A one standard deviation (4.1 percentage points) increase in the proportion of this ethnic group is associated with a 0.57 percentage point increase in the proportion of community schools in a postcode sector (the t statistic in the regression is 3.6). However, if we include the Indian subcontinent ethnic proportion in our main regressions for the South East, we find virtually no change in the school performance effect – the coefficient in a within postcode district IV regression shifts from 0.645 (s.e. 0.100) to 0.637 (s.e. 0.110).

[21] The performance advantage of church schools does not appear to be related to selective admissions procedures by Voluntary Aided schools (who may conduct interviews to determine religious convictions). Voluntary Controlled schools, where the LEA administers admissions, also have better pass rates.

In all regions, the IV estimates of the implicit price of Key Stage 2 are higher than the estimates using three-year means. This is, in part, surprising as we might expect there to be residual catchment area effects leading to an upward bias in the OLS estimates of the effect of schooling on house prices, which instrumenting by school characteristics should remove. The results suggest that this is not the principal source of bias in the OLS estimates, but that the use of year to year performance measures, and even 3-year averages, seriously downward biases the OLS estimates due to the noise components of these raw transitory measures. An alternative explanation is that the catchment area effects are so severe that the product of parameters $\alpha\beta$ in equation (14) is greater than one, suggesting that the within-area marginal effect of log house prices on Key Stage 2 is much greater than one. This seems unlikely given that we are exploiting the variation within quite narrow geographical areas. Indeed, our evidence from running the reverse regression of Key Stage 2 on log house prices or incomes (using property size as an instruments) suggests that the parameter is closer to 0.2 for log property prices.

The IV estimates also shift down when social housing is included, but by only 17% to 30%. The Sargan test statistics suggest that our instruments are not uncorrelated with the residuals from the regression *unless* we control for social housing density. This is consistent with our observation that Community schools are more likely to be located near local authority housing estates. This implies that the poorer performance of Community schools relative to religious schools is in part due to their catchment areas containing a higher proportion of local authority tenants. Based on the Column 6 models the minimum distance estimate across regions is now 0.773, which cannot be restricted to be equal across the tables (*p*-value = 0.040). This rejection no longer occurs if one just considers the South East/East and North results where the Instrumental Variables estimates of the implicit price of Key Stage 2 look very similar. For our preferred specification of column 6 the minimum distance estimate for these two regions is 0.84 (*p*-value = 0.48) implying an 8.8% premium (= exp{.084) – 1}X100) per 10% absolute improvement in Key Stage 2, once we control for local social housing. This amounts to about £10,800 for a 10 percentage point improvement, in London and the South East.[22]

[22] The property market in the West and South West is a peculiar case. If we exclude the South West Peninsula, the results look more like those in other regions. We suggest that the demand for second homes in Devon, Cornwall and Somerset obscures the relationship for this area.

How do these estimated implicit prices compare with private sector fees? In the private sector, the equivalent of primary schools are “preparatory” and “pre-prep” schools, covering the age-range from nursery to age 13. The total number of accredited nursery, pre-prep and prep schools in England on the Independent Schools Information Service (ISIS) database is 717, with nearly 40% of these in London and the South East. The mean national average reported by ISIS for 515 prep and pre-prep schools is £6324 in 2001. Assuming this is paid for eight years, and discounting at a rate of 5%, the present value of the costs of this investment amount to about £38,000. Unfortunately we have no information on Key Stage 2 level performance for private schools. But, we can guess that parents paying for private primary education would expect nearly everyone at the school to reach the equivalent Level 4 in Key Stage 2, implying a 25 percentage point advantage over the mean state sector primary school in 1999. In terms of property prices in the last quarter of 2000, this performance advantage would be worth around £22500 nationally, around £37000 in all the South East, and £45000 in London. This suggests that *for families with only one child* in London and the South East, the capitalised costs of state-sector primary education (over and above the unavoidable direct costs of taxation, and asssuming no re-sale of the property) are at least as high as the costs of a private-sector primary education. For families with, or intending to have, more than one child of primary school age, and for those in other areas of the country, moving house is probably a cheaper option. Even in the South East, the state-sector is cheaper in annual terms: the mortage costs associated with a 25 percentage point improvement amount to around £3000 each year.

5.2 Robustness

Table 3 summarises our parameter estimates under a range of alternative specifications. The first two rows show what we get if we specify postcode district geographical effects. These estimates are quite close to what we get with our smoothed spatial effects approach. Those readers worried about our use of school type as an instrument should note that our IV estimates are robust to exclusion of this from our instrument set. Using age range dummies as instruments, with population age range controls in the IV regressions, gives similar results (see Table 3, row 5).

The smooth spatial effects estimates are remarkably insensitive to an increase or reduction in the bandwidth. The central rows of the table show estimates using bandwidths corresponding to 1650 and 5000 households.

At the bottom of the table, there is more evidence that it is the long-run components of school performance which influence property prices. Compare the main results in Tables 2a-2c with the results at the bottom of Table 3. Our estimator here is the smooth spatial effects estimator at the same bandwidth choice. The only difference here is that the results in Table 3 constrain the non-parametric surfaces to be identical in each year, with yearly dummies capturing time effects (this is analogous to using area fixed effects and separate time dummies, compared to area-time effects in our main results). In this case, the OLS estimates based on yearly measures are around half of those in our main results, whereas the IV estimates are almost unchanged. This we attribute to the fact that constraining the spatial effects to be fixed across years allows the transitory, time series variation in school performance within postcode sectors an increased role in determining the estimated coefficient in the OLS estimates.

5.3 Comparing with cross-LEA boundary models

The results from cross-LEA boundary model outlined in section 0 are presented in Table 4. Given the extensive data analysis required here, these are reported for the Greater London area only. The important comparisons are between the first and second rows, and the third and fourth rows. Using non-instrumented yearly primary school performance measures (column 1), the estimates obtained using the cross-LEA boundary fixed effects and the smooth spatial fixed effects over the same area are very close in relation to their standard errors. Once we take three-year averages, or instrument school performance, the estimates diverge considerably, with the SSE estimates up to 50% lower. The SSE estimates are still never more than two standard errors below those obtained on adjacent postcodes with cross-boundary fixed effects. It should also be noted that these are very different samples – only LEA boundary postcode sectors in the cross-boundary models, but all postcode sectors in the region in the SSE models.

5.4 Changes over time

An obvious question here is whether the apparent premium on house prices associated with good primary schools is a recent phenomenon, stemming from the introduction of the published league tables for primary schools in 1996. Unfortunately we have no data on pre-1996 performance to test this directly. However, if the performance tables made a difference, we would expect there to be an increasing effect over time since 1997 (the year in which we assume the 1996 performance table would initially have an impact), in response to the diffusion of the sorting process. We tested this hypothesis by interacting time dummies with the school performance measures, but found no evidence of any growth in the effect since 1997. Repeating this using instruments for school performance and their time interactions gives us significantly negative coefficients on the interactions. The identification here relies on changes in the performance-school characteristics relationship over time, so is highly tenuous. There is, nevertheless, no hint here of any increase in the sensitivity of house prices to school quality since the publication of the performance tables.

5.5 Evaluating the returns to Key Stage 2 attainment

Using equation 7,

$$\frac{\partial \ln \bar{y}^c}{\partial x} = \frac{P_h}{k \cdot \bar{y}^c} \cdot \frac{\partial \ln P_h}{\partial x} \qquad (7)$$

we can tentatively infer the expected returns to future earnings from attainment of level 4 in Key Stage 2.[23] However, we need some further assumptions as we have no data on expected mean lifetime income of children. We do have family income for households in a commercial data set from CACI, so we can estimate expected family income of the next generation using an intergenerational mobility function:

$$y^c = \bar{y}^p + \rho \tilde{y}^p$$

[23] This calculation ignores the long-run, intergenerationally-transferable asset value of any increase in property value attributable to school performance.

where y^c is the child's family income, $\bar{y}^p$ is mean family income of the parent's generation, and $\tilde{y}^p$ is the deviation of own parents income from the mean. To parameterise ρ, we refer to the literature on intergenerational mobility (Dearden, Machin and Reed, 1997).[24] Assuming family income is received forever and applying a discount rate of 5% to calculate the present value of lifetime income, we can replace the variables in equation (7) with their postcode sector averages.

Using this method, our estimated median returns to Key Stage 2 Level 4 are around 0.2% to 0.3% for a 1 percentage point improvement in Key Stage 2 performance. This is based on 0.5 to 0.8 as an estimate of marginal effect of the probability of attaining Key Stage 2 on log property prices. The mean result is fairly insensitive to the choice of ρ (which mainly effects the variance), but will obviously depend on the discount rate applied. The result implies that, on average, parents expect the lifetime income of a child who attains Level 4 in Key Stage 2 to be between 20 and 30% higher than one who does not.

6 Conclusions

In this paper we address the policy relevant question asking how much parents are prepared to pay to get their children into better schools by moving house. We use postcode sector level data on house prices, incomes and primary school performance in the whole of England to estimate the magnitude of the association between primary school quality and local house prices and incomes. We eliminate the effects of catchment area wealth on pupils' achievements by concentrating on the effects within narrow geographical areas, and by instrumenting measured pupil achievements by characteristics of the school itself. Our best estimates imply a premium on postcode sector house prices of between 2.6% in the West and South West and 4.2% in the East, South East and North for each 5% improvement in the proportion of children reaching Key Stage 2, Level 4 at age 11. This translates into monetary valuations of the order of £2250 for the West Midlands, £2,800 for the South West, £2,900 for the North, £3,100 for the North West, £8,800 for London and £6,300 the South East (all at 2000 property prices).

[24] Values of 0.2, 0.4 and 0.8 were tried.

The large discrepancy between the London/South East and other areas is consistent with higher earnings in this region translating into higher expected returns in adult life from primary school attainments. Inference from our estimates, suggests that parents expect attainment at Key Stage 2, Level 4 to increase expected future earnings of their children by between 20 and 30%.

Interestingly, our estimates of the primary school effect are of the same order as those obtained for suburbs of Boston, Massachusetts by Black (1999). She finds that a 5% increase in primary school mean test scores attracts a 2.5% property price premium. Using time averages of school performance in our cross-LEA boundary model for London, we get a very similar estimate. Our lowest estimates based on OLS, within-area estimators put the figure at around 1.5% for a 5% school improvement.

The sensitivity of property prices to local primary school quality implies the existence of a back-door selection of pupils by the incomes of their families. This flies in the face of notions of equality of opportunity, is likely to restrict intergenerational mobility and generates an inequality of educational outcomes which may be unrelated to the abilities of children. If pupil ability is related to parental incomes then selection by income is implicitly selection by academic ability. Indeed, this goes against the principle in the DfEE code of practice on admissions (Section 5.6) that "academic ability should not be used to decide entry into primary education". The equilibrium arising from local sorting by incomes on primary school quality will be inefficient if the net marginal benefits of state school quality are greater for lower income families. This is almost certainly true given that the alternatives – private sector schooling, private personal tuition – are available at lower marginal cost to wealthier families with sufficient capital or lower borrowing costs. As usual with issues of educational equity, relaxation of borrowing constraints is a fundamental issue here. Linking of property loans to current incomes means that the marginal costs of borrowing become infinite at lower and lower purchase price thresholds as incomes decrease. This is sensible given the need to match lending to borrowers' ability to repay the debt, but leads to exclusion of those on low incomes from the benefits of good local schooling.

The obvious primary objective for policy seeking to remove inequities and inefficiencies arising from income-related selection on good state schools should be to eradicate differences in primary school quality across geographical space. Current government policy is to increase competition between schools as an incentive for good performance. However, proximity-based restrictions on admissions, together with the house price effects shown in this paper, mean that higher income families will inevitably benefit the most. Lower-income home-owners will be priced out of the best school catchment areas. More public information on school performance differences could exacerbate this problem, but we do not find evidence that house prices have become more sensitive to school quality over the years that the school performance league tables have been available.

Taking the distribution of school performance as given, it is hard to think of any uncontroversial policy response. Given the limitations on school size, some form of rationing is inevitable. "Local schools for local people" is still the current government thinking on this. Rationing on the basis of residential proximity reduces the aggregate costs incurred in getting kids to school on a day to day basis. Alternative, more equitable arrangements – such as a lottery amongst applicants – would probably prove unacceptable: children living next door to the school could find themselves excluded. Nevertheless, there is no obvious reason why close proximity to a school should confer a right of admission. Equity in primary school provision demands that proximity should, perhaps, take a lesser role in the school's over-subscription criteria.

The clear message from our results is that households value improvements in primary school performance. Importantly, this valuation appears to relate to differences that are attributable to exogenous schooling inputs, not simply to exogenous neighbourhood status. *From this we infer that school inputs must matter*. Lack of suitable data means we cannot empirically address the question of which inputs matter most. This is the appropriate question for policymakers who want a policy lever to apply, and more research on this question using detailed data on children and schools is vital. Nevertheless our findings are important in that they show that parents strongly value better school performance.

Further, an alternative explanation for our results is that certain observable school characteristics act as a focal point for high-income parents seeking high-income peer groups for their children. Our use of community/voluntary status as an instrument for school performance is open to this objection. Non-community status may offer no advantages in terms of expenditures, teaching techniques or other inputs, but historical belief that these schools are better may lead high income parents to converge on them. The performance advantage is then purely attributable to the characteristics of the children, or parents of the children, and the peer-group benefits of mutual association. Whilst this is plausible, it seems unlikely, as we get similar results when using only age range as an instrument. As far as we know, age-range is not widely used by parents as a signal of school quality.

If it is peer groups, and not school inputs that matter, then our results amount to a valuation of a peer-group effect in primary education. If neither peer groups nor inputs matter, so differences in school performance between school types are purely attributable to the distribution of child and parental characteristics at the school, then sorting on school types and the school-property price premium is irrational and inefficient. High income families would do better to send their children to schools which score low in the performance tables, where the attainments of their own children would be identical to their attainments at a 'good' school.

Extrapolating from our results, we can say that any technology which raises primary school standards by one percentage point has a social valuation per household equivalent to 0.5% to 0.8% of the local mean property price. For a national population of 21 million households, and national mean property price of £96700 at the end of 2000, this implies a maximum aggregate social valuation of £16,200 million, or about £1.35 million per school. If we include only the 18.5 million households who are resident in postcode sectors containing primary schools (under the assumption that those elsewhere place no value on primary schools) and take the lower estimate we get a lower bound of £8,900 million, or £0.71 million per school. This means that a sustained one percentage point improvement in primary school performance scores is valued at between £59 and £117 for each child of primary school age or younger.[25] Our lowest estimates, exploiting year on year and within-area variation in performance and prices give a figure of £44 per pupil child per year for a one percentage point improvement.

[25] These calculations assumes around 12500 primary schools, 7.6 million children age 11 and under and a 5% social discount rate.

Table 1: Descriptive Statistics

	East and South East	North	West and South West
A. Property prices (£)			
1996 sector mean	86591	52286	63221
1997 sector mean	98701	55879	69852
1998 sector mean	112303	61045	78600
1999 sector mean	125757	63921	85040
Mean sector sales volume, 1996-99	140	95	114
Detached house sector mean	165532	94006	110870
Semi-detached sector mean	106521	53254	65343
Terraced sector mean	96183	40375	54178
Flat/maisonette sector mean	69881	40607	43510
Number of postcode sectors	2900	2998	1554
B: School performance			
1996 key stage 2, level 4 proportion	0.598	0.584	0.592
1997 key stage 2, level 4 proportion	0.667	0.656	0.657
1998 key stage 2, level 4 proportion	0.665	0.648	0.657
1999 key stage 2, level 4 proportion	0.745	0.733	0.739
Proportion community school	0.643	0.635	0.609
Proportion of schools with pre-school/reception	0.229	0.346	0.200
Proportion of schools with infants	0.467	0.444	0.572
School roll	310.1	282.3	285.9
Number of age 11 pupils present	53.6	45.5	48.2
Number of schools in postcode sector	1.9	2.2	2.0
Number of postcode sectors	2289	2242	1164

Property prices are matched to lagged Key Stage 2 results in estimation sample

Price means are means of postcode sector means (unweighted by sales volume)

1999 Key Stage 2 results reported for completeness (not used in estimation sample)

Key Stage 2 assessment tests are sat in Spring and results are released in Autumn.

Table 2a: South East and East Property Prices: SSE models

	OLS	3-Yr Mean	IV	OLS	3-Yr Mean	IV	Means
Key stage 2	0.469	0.622	1.072	0.294	0.403	0.879	0.647
	(0.024)	(0.053)	(0.075)	(0.025)	(0.052)	(0.085)	
No primary school	0.398	0.504	0.796	0.267	0.342	0.658	0.165
	(0.018)	(0.038)	(0.050)	(0.018)	(0.037)	(0.057)	
Detached	0.481	0.483	0.481	0.480	0.483	0.480	0.229
	(0.003)	(0.005)	(0.003)	(0.003)	(0.005)	(0.003)	
Terraced	-0.186	-0.188	-0.186	-0.186	-0.188	-0.185	0.268
	(0.002)	(0.003)	(.002)	(0.002)	(0.003)	(0.002)	
Flat/Maisonette	-0.592	-0.586	-0.592	-0.592	-0.586	-0.592	0.242
	(0.003)	(0.005)	(.003)	(0.003)	(0.005)	(0.003)	
Social housing tenants	-	-	-	-0.738	-0.720	-0.478	0.190
				(0.042)	(0.078)	(0.054)	
Sargan test *p*-value	-	-	.014	-	-	0.218	
Within area R^2	0.836	0.836	.851	0.840	0.841	0.850	
Overall R^2	0.928	0.929	.926	0.930	0.931	0.928	
Sample size	29606	9972	29606	29606	9972	29606	

Min, mean, max bandwidth: .23 km, 1.43 km, 9.25 km

Mean of dependent variable (log-price) columns 1,3,4,6 = 11.46

Mean of dependent variable (log-price) columns 2,5 = 11.58

School performance means are conditional on school observed.

Sample comprises unbalanced panel with up to 4 house-price observation types (Detached, Semi-Detached, Terraced, Flat) for each postcode sector, observed for 1997, 1998 and 1999 (1999 only in columns 2 and 5)

School performance measures are the proportion in the school obtaining Key Stage 2 at Level 4 and above. Key Stage 2 results are average of maths, reading and science scores. Key Stage 2 school results instrumented by community school dummy and age-range dummies.

Standard errors corrected for clustering on 2898 postcode sectors (in parentheses).

Table 2b: North Property Prices: SSE models

	OLS	3-Yr Mean	IV	OLS	3-Yr Mean	IV	Means
Key Stage 2	0.507	0.663	1.054	0.339	0.441	0.798	0.640
	(0.025)	(0.027)	(0.069)	(0.027)	(0.058)	(0.077)	
No primary school	0.412	0.525	0.762	0.286	0.365	0.583	0.190
	(0.019)	(0.040)	(0.046)	(0.020)	(0.043)	(0.052)	
Detached	0.525	0.541	0.525	0.525	0.540	0.524	0.261
	(0.003)	(0.005)	(0.003)	(0.003)	(0.005)	(0.003)	
Terraced	-0.280	-0.280	-0.280	-0.278	-0.278	-0.278	0.310
	(0.003)	(0.004)	(.003)	(0.003)	(0.004)	(0.003)	
Flat/Maisonette	-0.406	-0.392	-.406	-0.404	-0.392	-0.405	0.114
	(0.006)	(0.010)	(.006)	(0.006)	(0.010)	(0.006)	
Social housing tenants	-	-	-	-0.672	-0.692	-0.541	0.221
				(0.043)	(0.079)	(0.048)	
Sargan test *p*-value	-	-	0.026	-	-	0.382	
Within area R^2	0.810	0.778	0.810	0.800	0.786	0.810	
Overall R^2	0.875	0.874	0.875	0.883	0.878	0.881	
Sample size	25431	8544	25431	25431	8544	25431	

Min, mean, max bandwidth: 0.34 km, 1.72 km, 26.07 km

Mean of dependent variable (log-price) columns 1,3,4,6 = 10.88

Mean of dependent variable (log-price) columns 2,5 = 10.92

School performance means are conditional on school observed.

Sample comprises unbalanced panel with up to 4 house-price observation types (Detached, Semi-Detached, Terraced, Flat) for each postcode sector, observed for 1997, 1998 and 1999.

School performance measures are the proportion in the school obtaining Key Stage 2 at Level 4 and above in previous year. Key stage 2 results are average of maths, reading and science scores. Key Stage 2 school results instrumented by community school dummy and age-range dummies.

Standard errors corrected for clustering on 2992 postcode sectors (in parentheses).

Table 2c: West and South West Property Prices: SSE models

	OLS	3-Yr Mean	IV	OLS	3-Yr Mean	IV	Means
Key Stage 2	0.441	0.600	0.741	0.264	0.374	0.520	0.640
	(0.035)	(0.075)	(0.104)	(0.036)	(0.079)	(0.116)	
No primary school	0.397	0.498	0.594	0.270	0.342	0.439	0.218
	(0.025)	(0.053)	(0.069)	(0.026)	(0.056)	(0.077)	
Detached	0.497	0.503	0.498	0.497	0.502	0.497	0.267
	(0.003)	(0.005)	(0.003)	(0.003)	(0.005)	(0.005)	
Terraced	-0.191	-0.191	-0.191	-0.190	-0.189	-0.190	0.174
	(0.003)	(0.005)	(0.003)	(0.003)	(0.005)	(0.003)	
Flat/Maisonette	-0.482	-0.488	-0.482	-0.480	-0.485	-0.480	0.276
	(0.005)	(0.009)	(0.005)	(0.005)	(0.009)	(0.005)	
Social housing tenants	-	-	-	-0.829	-0.795	-0.711	0.183
				(0.057)	(0.100)	(0.074)	
Sargan test *p*-value	-	-	0.084	-	-	0.151	
Within area R^2	0.827	0.824	0.833	0.832	0.828	0.835	
Overall R^2	0.898	0.897	0.897	0.900	0.900	0.900	
Sample size	15605	5274	15605	15605	5724	15605	

Min, mean, max bandwidth: 0.42 km, 1.86 km, 11.09 km

Mean of dependent variable (log-price) columns 1,3,4,6 = 11.09

Mean of dependent variable (log-price) columns 2,5 = 11.17

School performance means are conditional on school observed.

Sample comprises unbalanced panel with up to 4 house-price observation types (Detached, Semi-Detached, Terraced, Flat) for each postcode sector, observed for 1997, 1998 and 1999.

School performance measures are the proportion in the school obtaining Key Stage 2 at Level 4 and above in previous year (average of maths, reading and science scores).

Key Stage 2 school results instrumented by community school dummy and age-range dummies.

Standard errors corrected for clustering on 1554 postcode sectors (in parentheses).

Table 3: Sensitivity of Property Price Models to Specification

	South and East		North		West and South West	
	Annual	IV	Annual	IV	Annual	IV
Within pc-district-year, + type dummies	0.409 (0.029)	0.717 (0.098)	0.566 (0.031)	1.038 (0.092)	0.465 (0.048)	0.692 (0.111)
Within pc-district-year, + type dummies, social housing	0.266 (0.031)	0.633 (0.108)	0.315 (0.028)	0.775 (0.106)	0.278 (0.047)	0.538 (0.128)
IV, within pc-district, using age-range instruments only	-	0.670 (0.181)	-	0.954 (0.136)	-	0.721 (0.525)
1650 hhs. yearly spatial effect, + type dummies	0.501 (0.037)	1.090 (0.106)	0.502 (0.034)	1.125 (0.102)	0.422 (0.046)	0.845 (0.152)
Overall R^2	0.937	0.936	0.897	0.894	0.911	0.910
Sargan test *p*-value	-	0.634	-	0.615	-	0.267
1650 hhs. yearly spatial effect, + type, social housing	0.322 (0.037)	0.859 (0.122)	0.355 (0.036)	0.889 (0.108)	0.264 (0.048)	0.671 (0.171)
Overall R^2	0.938	0.937	0.899	0.898	0.912	0.911
Sargan test *p*-value	-	0.979	-	0.860	-	0.080
Mean bandwidth	1.0 km		1.2 km		1.3 km	
5000 hhs. yearly spatial effect, + type dummies	0.452 (0.021)	0.991 (0.064)	0.529 (0.020)	1.060 (0.060)	0.457 (0.030)	0.733 (0.084)
Overall R^2	0.924	0.920	0.865	0.860	0.887	0.886
Sargan test *p*-value	-	0.001		0.002		0.054
5000 hhs. spatial effect, + year, type, social housing	0.286 (0.022)	0.834 (0.071)	0.341 (0.024)	0.792 (0.069)	0.267 (0.031)	0.527 (0.093)
Overall R^2	0.930	0.920	0.870	0.867	0.891	0.891
Sargan test *p*-value	-	0.062	-	0.135		0.126
Mean bandwidth	1.8 km		2.1 km		2.3 km	
3300 hhs. fixed spatial effect, general year effects, type dummies	0.259 (0.024)	1.049 (0.123)	0.281 (0.024)	1.036 (0.114)	0.176 (0.033)	0.765 (0.165)
Overall R^2	0.921	0.912	0.864	0.852	0.816	0.878
Sargan test *p*-value	-	0.159	-	0.206	-	0.371
3300 hhs. spatial effect, + year, type, social housing	0.159 (0.021)	0.872 (0.137)	0.173 (0.024)	0.780 (0.122)	0.080 (0.030)	0.554 (0.177)
Overall R^2	0.923	0.916	0.869	0.861	0.888	0.884
Sargan test *p*-value	-	0.510	-	0.649	-	0.446
Mean bandwidth	1.4 km		1.7 km		1.9 km	

Table 4: Comparison Of Coefficients From Cross-Local Authority Boundary Effects, And Alternative Estimators For Greater London Area

	Annual Key Stage 2	1999 on mean 96-98 KS2	Annual, IV
Dummy variables for adjacent postcode sectors across Local Authority boundary, Local Authority, year, property type and no-school	0.420 (0.069)	1.030 (0.175)	1.295 (0.391)
Comparable SSE model without social housing control	0.492 (0.044)	0.630 (0.091)	0.819 (0.111)
Dummy variables for adjacent postcode sectors across Local Authority boundary, year, property type and no-school, plus social housing proportion	0.203 (0.058)	0.533 (0.188)	1.204 (0.355)
Comparable SSE model with social housing control	0.290 (0.040)	0.362 (0.076)	0.680 (0.114)

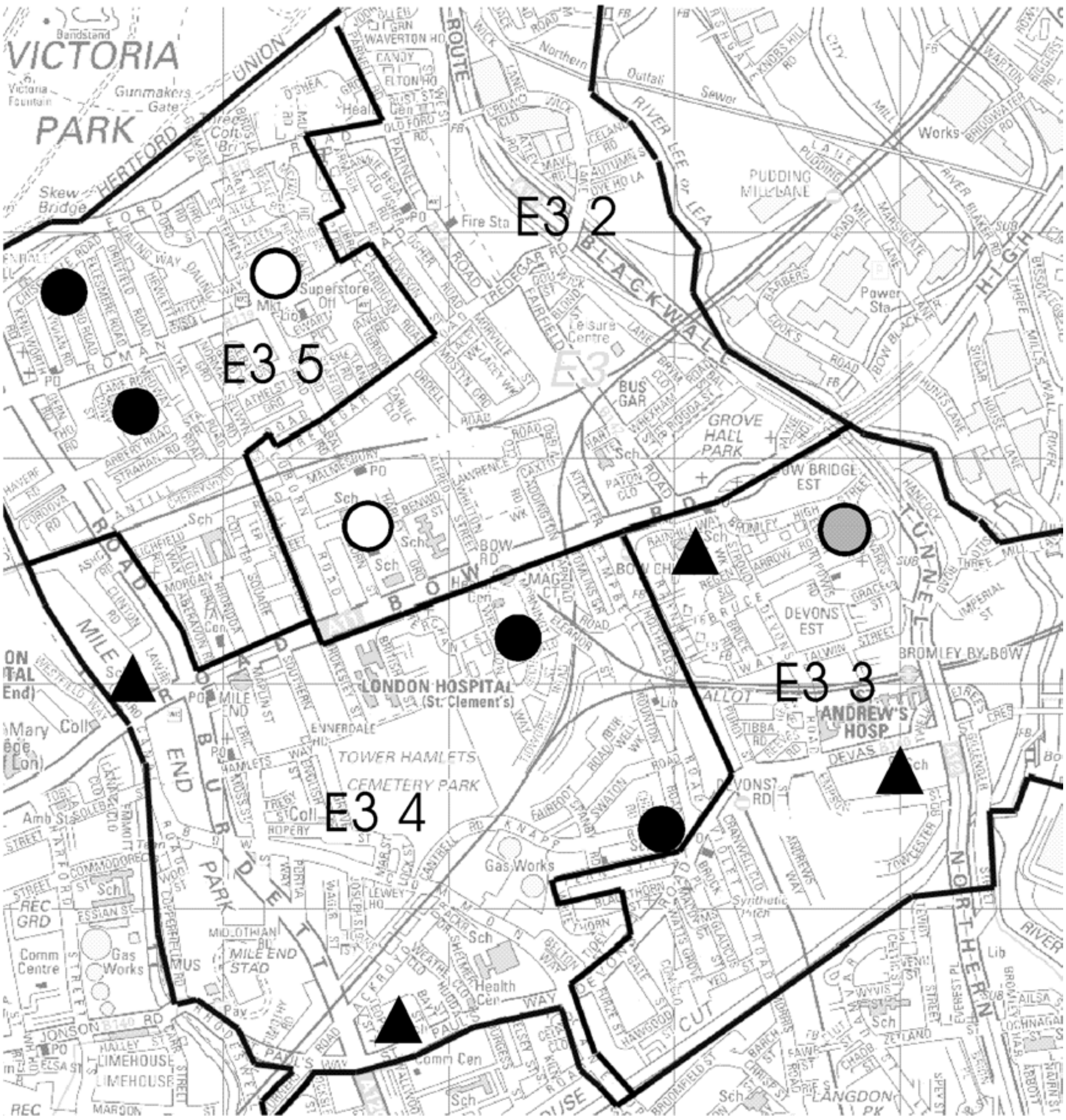
Sample size (sectors x property types x years) = 4008 based on all postcode sectors adjoining local authority boundaries, on Geoplan Greater London postcode sector map

Sample size (sectors x property types x years) = 11051 in SSE model using all sectors between eastings 50100 and 56000, northings 15000 and 21100,

Standard errors adjusted for clustering on postcode sectors (except postcode sector fixed effect models)

Around 80% of the variation in Key Stage 2 performance in the panel is attributable to cross-sectional variation across postcode sectors

Figure 1: Example Postcode District, Postcode Sectors and Geographical Distribution of School Types



● All ages ◍ No nursery ○ Junior only ▲ Voluntary Aided

Figure 2: Postcode District Mean Key Stage 2 Performance, Illustrating Regional Division

Figure 3: Relationship Between Log House Prices in 1999 and Mean 1996-1998 Primary School Performance – Deviations From Postcode Sector Means

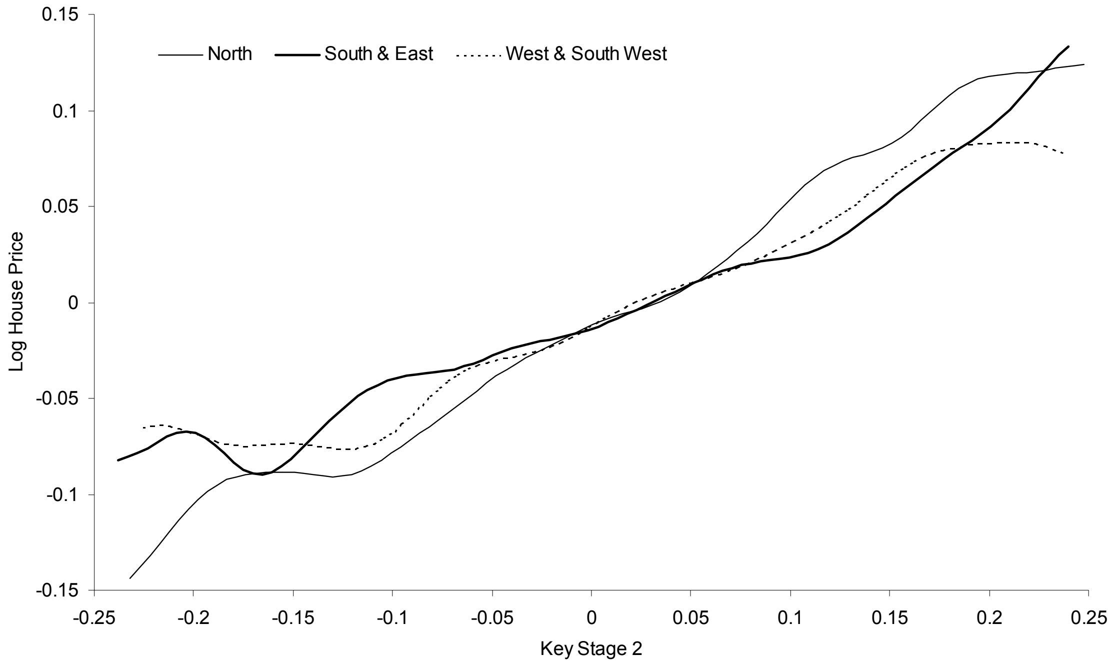
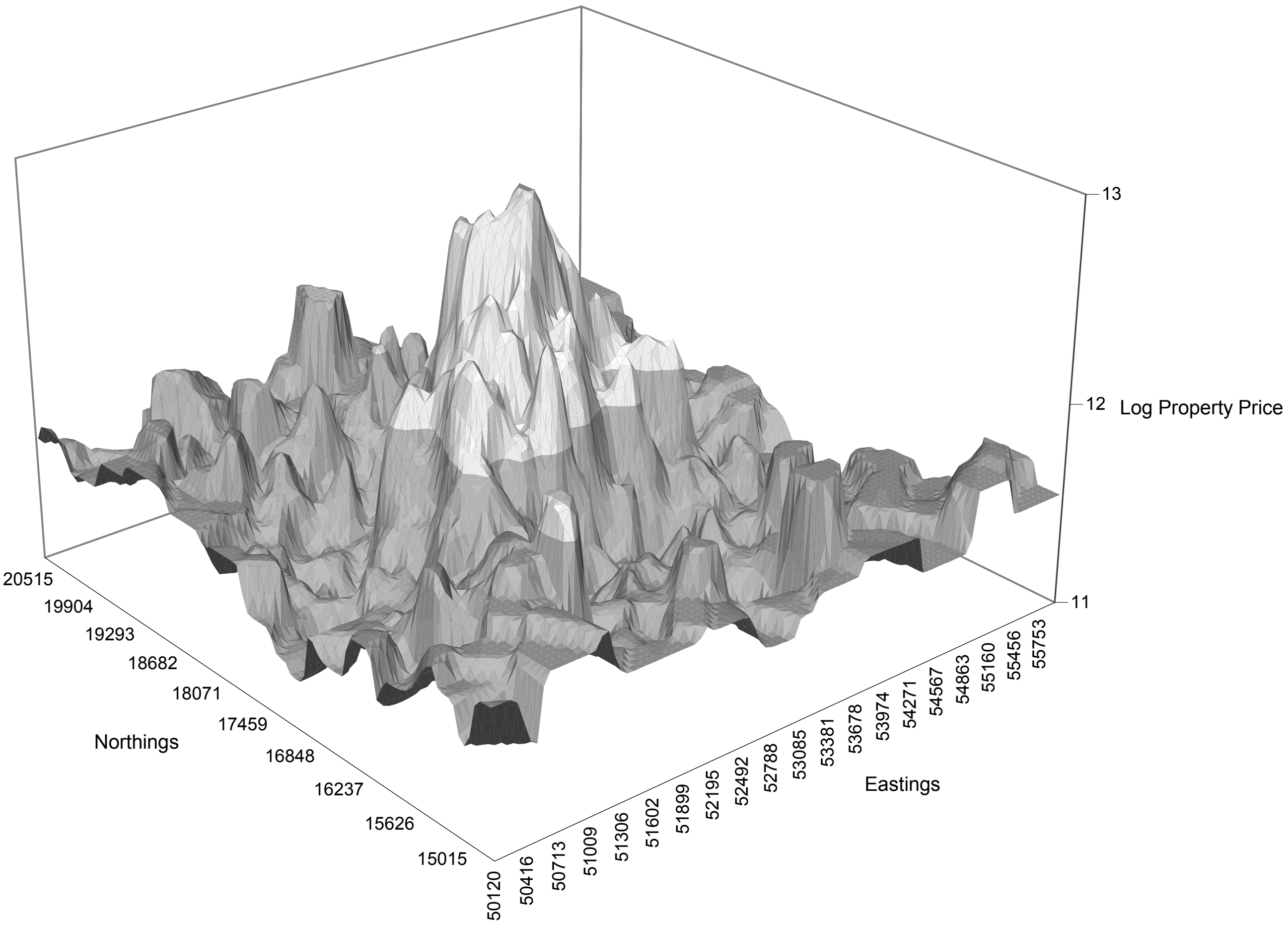


Figure illustrates kernel regression of within-postcode-district variation in log house prices on within-postcode-district Key Stage 2 performance. Bandwidths in accordance with Silvermann's rule of thumb (0.02 for North and South and East, 0.025 for West and South West

Figure 4: Example House Price-Location Surface For London, From Smooth Spatial Effect Model



Appendix A

Bandwidth choice

The choice of bandwidth for the kernel in our SSE estimator is important, since the appropriate comparison needs to encompass more than one postcode sector, without averaging over too broad an area. Since the appropriate area (in terms of geographical distance) depends on local household density, we need to take this into account.

Postcode district HG4, just north of Harrogate, has an area of roughly 270 km^2 and postcode sector household densities that range from 20 to 1300 per km^2. By contrast, E3 around Bow and Tower Hamlets in east London has an area of roughly 4.5 km^2 and household densities between 6000 and 6800 per km^2. No fixed bandwidth can accommodate this variation: a suitable bandwidth choice at HG4 will average over much of the London area if applied to a sector in E3. A bandwidth suitable for E3 if used in HG4 will apply virtually no weight to any observations beyond the postcode sector. Consequently, we weight the neighbourhood bandwidth using data on household density matched in from the 1991 Census.

Fixing the number of households n in a circular spatial group of radius b, gives us a bandwidth weighting rule dependent on housing density h:

$$b = \sqrt{\frac{n}{\pi h}} \tag{20}$$

In order to choose a bandwidth regulator h, it is useful to know how our postcode sectors relate to primary school catchment areas. This is made more difficult by the fact that we could obtain almost no information on this from our enquiries to LEAs, as catchment areas are rarely precisely defined, and vary with demand. Data on addresses of pupils actually attending is considered confidential, and is usually held only by the schools themselves. We were unable to obtain this. From our primary school performance data, the total number on the school role of primary schools recorded in the 1999 performance tables is 3.77 million and the total number of imputed households in our CACI data is 20.1 million. The ratio of households to primary school children is 5.33, implying an average catchment area of around 1400 households, which is about half a postcode sector. This is consistent with the fact that there are, on average, two primary schools per postcode sector in the school performance tables.

Choosing bandwidths corresponding to groups of roughly one, two and three postcode sectors and adjusting downwards by 40% to compensate for the use of a Gaussian kernel (which applies non-zero weights to observations outside the bandwidth window), suggests corresponding household groups of roughly 1700, 3400 and 5000 respectively. The main results we present use bandwidths corresponding to 3400 households, but comparisons are made with other bandwidth choices.

Appendix B

Attenuation from transitory performance measures

Using transitory measures of school performance as a regressor when we want the response to permanent changes in school performance biases the response estimates downwards. Inclusion of other variables which proxy for long-run performance attenuates the coefficient still further, and leads to misleading coefficients on the newly included variable. This is a standard result from the classical measurement error problem. To see this in context, write measured school performance as a mixture of a long-run component plus an uncorrelated transitory component. The permanent component is itself a function of local a local community characteristic z_i, say the proportion of social housing in the neighbourhood.

$$x_i = x_i^p + x_i^t \qquad 21$$

$$x_i^p = z_i + \upsilon_i \qquad 22$$

Assume that house prices p_i depend on permanent school performance, but that home-owners have no direct disutility from z_i.

$$p_i = \beta x_i^p + \varepsilon_i \qquad 23$$

If we run the regression

$$p_i = \beta_1 x_i + u_i \tag{24}$$

then the probability limit of the OLS estimate of β_1 is:

$$\text{plim}\,\hat{\beta}_1 = \beta_1 \cdot \frac{\sigma^2_{x^p}}{\sigma^2_{x^p} + \sigma^2_{x^t}} \tag{25}$$

In the regression

$$p_i = \beta_1 x_i + \beta_2 z_i + u_i \tag{26}$$

the probability limit is

$$\text{plim}\,\hat{\beta}_1 = \beta_1 \cdot \frac{\sigma^2_{\upsilon}}{\sigma^2_{\upsilon} + \sigma^2_{x^t}} \tag{27}$$

whereas, for β_2, structurally zero, we have:

$$\text{plim}\,\hat{\beta}_2 = \beta_1 \cdot \frac{\sigma^2_{x^t}}{\sigma^2_{\upsilon} + \sigma^2_{x^t}} \tag{28}$$

Appendix C

Details of the data sources

Data on individual housing transactions is unavailable in Britain, so we have used the best available alternative: house prices aggregated to postcode sector level. This data set covers the whole of England and Wales, and is available from 1995 to 2000. It contains mean house prices and total sales volumes at postcode sector for each postcode sector, where annual sales numbered 3 or more. Properties sold for under £10,000 and over £1,000,000 are excluded. This amounted to only 0.5% of all property sales in 1999.

In the UK, postcodes contain up to seven alphanumeric characters, and contain four hierarchical components. The first two alphabetic characters define the Postcode Area, the broadest postal zone. Examples are N, EX and YO representing North London, Exeter and York. Within Postcode Areas, the next level down is the Postcode District. This is defined by a single or two-digit number following the Postcode Area. Examples are N6, EX24, and YO10. A single letter further subdivides some postcode districts in central London. Below this, we have Postcode Sectors. This is the unit of observation in our house price data set.

The school performance tables for England compiled by the Department for Education and Employment (DfEE) provide the basis for our school performance measures. We have the 1999 primary and secondary school tables, which include background information on the schools in 1999, plus the performance measures for years 1996 to 1999 inclusive. We also have the original data for the years 1996-1998 which includes the school background characteristics for these years. The primary performance measures are proportion of pupils reaching Level 4 (the target level of attainment) in the Key Stage 2 standard assessment tests administered at age 11. We average the measures for Maths, Reading and English tests. We average these school performance measures and characteristics across schools within each postcode sector to provide a postcode sector level primary school performance indicator and characteristics. Here, we experimented with simple means and school-size weighted means, but opted for the former on the basis that weighting by school size conflates school size and school performance issues. In practice, the choice of scheme made little difference to our results.

We match postcode sector house prices to the postcode sector school performance and characteristics from the school data set, giving us up to four house prices (detached, semi-detached, terraced, flat/maisonette) for each postcode sector in each year.

Additional variables at postcode sector level are derived from the 1991 Census, and from the 1998 postcode to Census enumeration district directory, which relates 1998 postcodes to corresponding 1991 census area codes. These sources give us geographical data including the national grid reference, the proportion of social housing, and the density of households per kilometre-squared. Although postcode-sector aggregated census data is available, the postcodes relate to the 1991 postcode geography, so the census variables we use are means of the values in the enumeration districts which are wholly or partly included in a given postcode sector. Grid references are taken as the mid point between the maximum and minimum in each direction.

No population bases are available at the postcode sector level later than 1991, though we have household figures in our CACI data set on household incomes. The mean number of household addresses per postcode sector in the CACI data in 1999 is 2800. In the UK there are 26 million postal addresses, 2901 districts and 9624 sectors, so a crude average is 9000 per postcode district, 2700 per sector. These numbers change over time with changes in the postcode geography. In 1996, the number of households in England was 20.2 million, implying an average of around 9600 households per postcode district, and around 2560 in each postcode sector.

Appendix D

Table D1: Underlying prediction equations for IV estimates

	All areas	South East and East	North	West & South West
Community school – LEA appointed governors and admissions	-0.064 (0.004)	-0.069 (0.006)	-0.047 (0.007)	-0.074 (0.008)
School has pre-school/ reception years	-0.037 (0.006)	-0.041 (0.010)	-0.026 (0.009)	-0.036 (0.016)
School has infants and junior years	0.041 (0.005)	0.022 (0.007)	0.072 (0.009)	0.047 (0.009)
F-test of instruments	F(3,2058) = 182.6 P = 0.0000	F(3, 854) = 72.6 P = 0.0000	F(3,713) = 75.7 P = 0.0000	F(3,503) = 49.2 P = 0.0000

Predicted Key Stage 2 performance, from identifying instruments (all areas):
s.d. = 0.028
max = 0.110
min = -0.101

Models include property type dummies, proportion of local social housing, and are estimated within postcode-district-year groups

Standard errors (and F-tests) corrected for clustering on postcode districts.

Results shown for illustration only; estimation of main models does not use 2-stage least squares method.

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