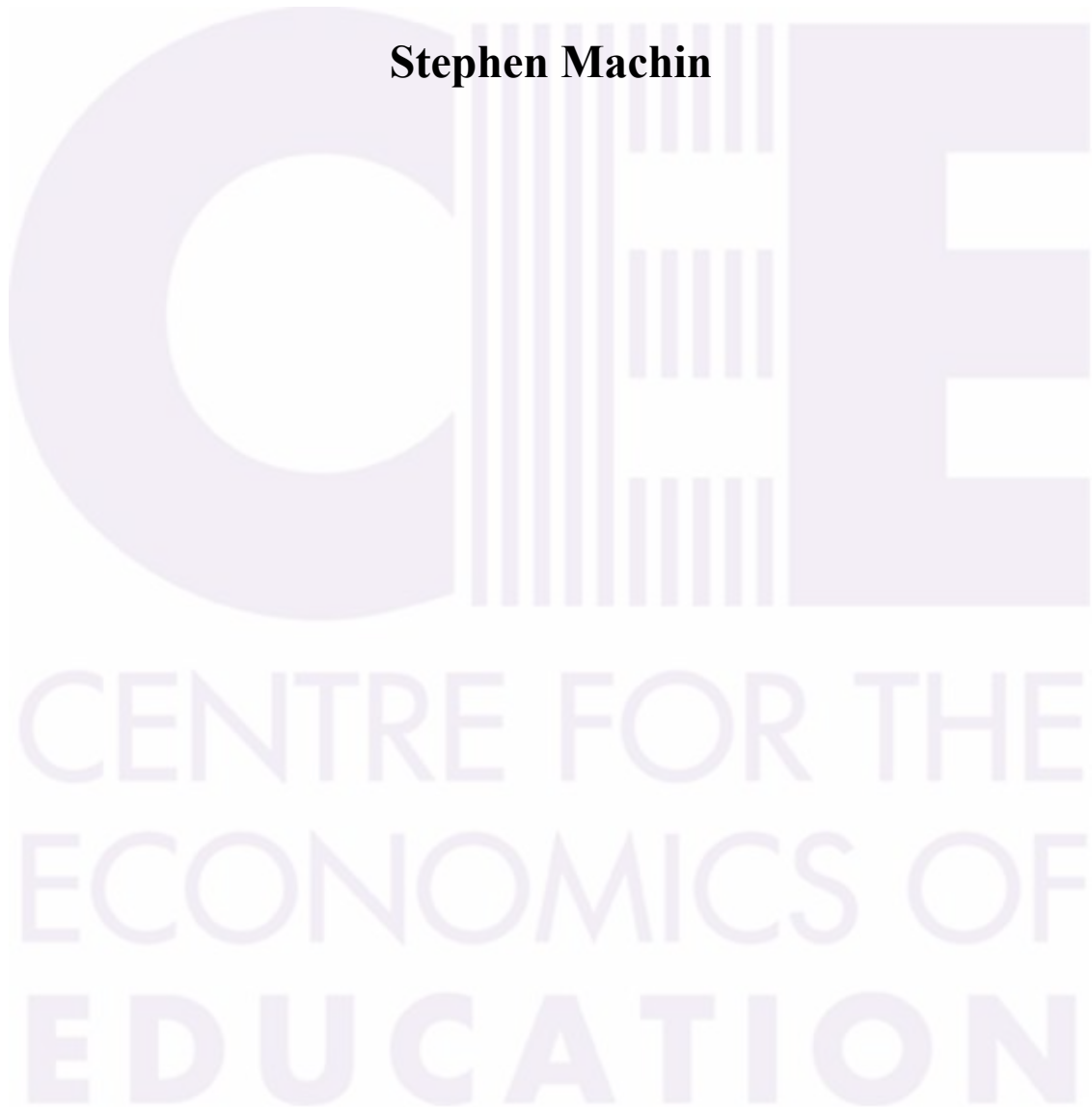


# **Paying For Primary Schools: Supply Constraints, School Popularity or Congestion?**

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## **Executive Summary**

Anyone with school age children worries about getting the best school for their child. However, the processes by which school choices are made, or indeed whether one gets an opportunity to choose, are complex. Some opt for education outside the state sector - if they can afford it. Others must adopt some other strategy to try to get their child into a decent state school. In the English school system, this generally means choosing a home near the school, because admission is restricted to those who live close by. The implications of this for house prices are well known, both through anecdote and media coverage. There is also an emerging body of harder evidence that these patterns of demand for neighbourhood schools are important. In this study we extend existing work to look more closely at how decisions over primary schooling are revealed in house price patterns.

We consider some special features of the English school admissions system that add to the complexity of the decision process. For a start, catchment areas are vaguely defined, and it is usually a question of ‘nearest-in-first-in’. This generates uncertainty about which residential locations are best. The problem is compounded by the fact that schools have limited number of pupil places, usually capped by a limit to class sizes and the number of classroom spaces, but parents do not know for certain whether a school will be over or under-subscribed. Parents also have imperfect and confusing information about school quality. Faced with wide disparities in state school performance, they scrutinise performance ‘league tables’, study Ofsted reports, and listen attentively to dinner party chat, to work out where the good schools are. We ask how these issues affect the process of school choice and investigate their influence on house price.

In common with other studies, we show a house price premium related to the performance of the nearest primary schools. But some of our findings run counter to common perceptions:

- A ten-percentage point improvement in the 'league-table' performance (at age 11, Key Stage 2) adds at least 3 per cent to the price of properties located next to the school.
- Despite this, primary schools are, in general not desirable local amenities. Only the 1-in-10 top performing schools will, on average, generate significantly higher prices in their immediate surroundings.
- The premium paid for 'league-table' performance is higher if local schools are over-capacity. There is also a premium for living close to an over-capacity, even if the league table performance is not outstanding. We interpret this as evidence of 'herd' behaviour in school choice. An over-capacity school is a popular school, and so - in the eyes of eager parents - a good school.
- Although a school that is over-capacity this year will likely be hard to get into in the next year, this does not seem to drive up the price of houses very close to good schools relative to those more distant.
- Unsurprisingly, the influence of primary school 'league-table' performance falls quite rapidly with distance, and the effect is halved by about 600m

These findings show that primary school performance is a valuable local commodity. This adds weight to the argument that school admissions procedures lead to 'selection by income' at primary school level. At current prices, parents can expect a move from an average dwelling outside a weak school, to one outside a top over-subscribed school, to cost around £61000 (26 per cent of the mean property price in London and the South East in April-June 2004). However, the results also show that the same improvement in less popular, under-capacity schools will cost around £12000 less.

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## **1 Introduction**

Anyone with school age children worries about getting the best school for their child. However, the processes by which school choices are made, or indeed whether one gets an opportunity to choose, are complex. Some opt for education outside the state sector - if they can afford it. Others must adopt some other strategy to try to get their child into a decent state school. In the English school system, this generally means choosing a home near the school, because admission is restricted to those who live close by.

It is therefore not surprising that the issue of which schools are viewed as better features prominently in the dialogue of parents. House prices and residential location decisions are a strong point of discussion, and in this perceptions of what constitutes a better school are important. As in other group discussion environments, some talking points are likely to take place on the basis of limited (or maybe out-of-date) information and it is evident that this may shape the views of parents on schooling decisions for their children. This forms the backdrop for what we study in this paper, namely the links between primary school performance, residential location, school capacity and house prices. We set up and test various models of school choice, implementing empirical tests using detailed house price and school data in London and the South East of England.

The primary school admission system is organised in England such that there is no deterministic relationship between location of residence and the primary school attended. In fact, allocation purely on the basis of place of residence became illegal in

the 1990s, after some well publicised court cases. In principle, parental preference is what counts. In practice, good primary schools in urban areas are often full or over-subscribed, and a number of geographically-based over-subscription criteria come into play. Living within some defined ‘catchment area’ can be important<sup>1</sup>; but it is often just a case of nearest-in/first-in.

A standard approach to placing a monetary valuation on school quality is to trace out the effects of neighbourhood school quality on property values. But the ‘nearest-in/first-in’ feature of the admissions system in England generally rules out empirical strategies that exploit well defined attendance district boundaries [as used in US work like Black (1999), or Bogart and Cromwell (2000)]. For primary schools, the only case where boundaries will be fairly non-porous is at the border between Local Education Authorities (LEAs).<sup>2</sup> These are the local government bodies (150 of them in England, around 20 percent of which are in London) that typically manage school funding and admissions. We used this particular boundary feature in Gibbons and Machin (2003) and exploit it again here. But we also need a more general approach for the majority of cases when LEA boundaries are not relevant.

The porous nature of school admissions geography implies that residence-school distance should have important impacts on the premium homebuyers pay for residences at locations close to good schools. This issue is one that has received little attention [though see Des Rosiers et al (2001) and some of the results in Kane et al (2003) for

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<sup>1</sup> Obtaining systematic well-defined information on catchment areas for Local Education Authorities (LEAs) is extremely difficult. However, it is clear that a great deal of heterogeneity exists across the country. In some LEAs well-defined catchment areas do exist, in others they change over time, and in others even defining a line around a catchment area proves difficult.

<sup>2</sup> This boundary feature is much less applicable to secondary schools, where pupils are more likely to cross LEA borders.



exceptions], and is a central focus of this paper. We are also interested in how admission constraints impact on the valuation of primary school performance. Parents' willingness to pay will clearly depend on whether there are constraints, or queues, to get their children into their preferred school. We thus develop further the standard hedonic valuation method [see Rosen (1974) for the classic exposition, or Sheppard (1999) for a modern survey] to provide different valuations for parents in the presence and absence of school admission constraints.<sup>3</sup> In the standard approach an estimate of the implicit price of school productivity is available from a simple regression of property prices on local school performance measures where one assumes school admissions are restricted to local residents. In our analysis we generalize this to allow for the fact that just living in the local neighbourhood of a particular school may not guarantee a child's attendance at that school, because some schools may be over-subscribed. Doing so permits us to test between different reasons as to why parents are willing to pay more for houses near better performing primary schools.

The remainder of the paper is structured as follows. Section 2 is devoted to model development where we present a framework showing how we would expect parental valuation to depend on school distance, and how admission constraints may impact on these relationships. We look at three models, respectively based upon supply constraints, school popularity and congestion effects, and generate empirical predictions from each. In Section 3 we describe the data and empirical methods we use. In Section 4 we present our estimates, and relate them back to the theoretical models presented earlier. Finally, Section 5 concludes.

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<sup>3</sup> A parallel issue is the effects of housing supply on the rate of capitalisation of local public goods. This is explored in Cheshire and Sheppard (2003). We focus here on constraints on the supply of the local public good itself.

## 2 Admission Constraints: Distance to School and School Capacity

### Distance to school and school quality

The special features of the English schooling system mean that choosing a residence in a particular location does not guarantee admission to a school. Instead, probability of admission increases as distance of residential address from the school decreases. Transport costs also increase with distance. An obvious implication of both these factors is that parents' willingness to pay for school quality through property prices at a given residential location must be decreasing in residence-school distance. Assume further that household residential choices are constrained to a general locality by labour market and broader housing issues, so that parents are really interested in the performance of neighbourhood schools relative to what can be expected in the general locality. The school quality  $q$  offered by a particular residential location then depends on neighbourhood school  $i$ 's test score performance,  $s_i$ , defined relative to the mean in the locality,  $\bar{s}$ , as  $s = s_i - \bar{s}$ . But it also depends on residence-school distance,  $d$ . For the moment, assume this is the distance to the nearest school.<sup>4</sup>

We define a school quality function  $q(s, d)$  to represent the effective supply of school quality available at a residential location at distance  $d$  from a school with performance  $s$ . Some plausible restrictions are that  $q(s, 0) = s$ ,  $q(s, \infty) = 0$ . This just says that school quality at the school gate is the same as that of the school itself, but school quality at a large distance is just average performance ( $s_i = \bar{s}$ ). If  $s > 0$  (where  $s_i > \bar{s}$ )

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<sup>4</sup> In the empirical section we work with harmonic mean distance to the nearest three primary schools.

then effective quality  $q$  decreases with distance:  $q_d(s, d) < 0$ . If  $s < 0$  the inequality is reversed.

### **Admission constraints**

In this setting school admission constraints can act as an important feature in parental choice. Class size, infrastructure, resource and institutional constraints mean that schools cannot expand indefinitely in response to high demand. Let us define two types of school: admissions-unconstrained, in which pupil numbers do not generally exceed institutional capacity, so over-subscription criteria are irrelevant; and admission-constrained, in which pupil numbers have reached or exceeded institutional capacity, so that the school's over-subscription criteria become important.

We propose three models, each with different predictions for the ways in which school constraints have some bearing on parental choice and thus on willingness to pay:

#### 1). Supply Constraints

Firstly, in a supply constraint model, school capacity may have an impact on the school quality available at a given school-distance because it limits the supply of school quality over distance. This happens if there is an increased probability of exclusion at any distance, due to more stringent proximity-based admissions criteria. Under this scenario, expected quality erodes rapidly with distance from over-capacity good schools (and improves rapidly with distance from bad schools).<sup>5</sup> Let us add school capacity

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<sup>5</sup> In principle, quality decreases with distance from under-capacity good schools only because of transport costs, or because there is uncertainty about availability at the time households make their choices. In any case, there could be some institutional bias in favour of applicants from residences neighbouring a school,

$\sigma \in \{0,1\}$  as an argument to the school quality function, with 1 indicating an admissions-unconstrained, or under-capacity, school. Now, the absolute value of the slope of the distance decay function is always less for under-capacity schools:

$$|q_d(s,d,1)| < |q_d(s,d,0)| \quad \forall d .$$

## 2). School Popularity

A second possible link between parental demand and school capacity arises where schools are likely to be admissions constrained because of earlier popularity. We term this the school popularity hypothesis. In this case, full capacity can act as a signal of expected school quality that might not be fully revealed in school performance indicators based on pupil test scores. Or it can mislead parents into believing a school is successful, even if school performance is not particularly good. In this case, high-performing schools that are at or over-capacity are likely to push up house prices more than high-performing schools that are under-capacity. School admissions constraints need not have an impact on the way the school performance premium changes with distance, but are likely to affect prices directly, or influence the sensitivity of prices to performance at any given school-distance. In this case, school over-capacity signals popularity, which interacts positively with performance in terms of perceptions of school quality, and willingness to pay. This implies that  $q_s(s,d,1) < q_s(s,d,0) \quad \forall s,d$ .

The supply-constraint and school popularity models are illustrated in . The upper Figure is the supply-constraint model, where perceived school quality declines with distance from better performing schools, and increases with distance from worse

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even in under-capacity schools. But, in general, if school capacity acts as a supply constraint, then expected school quality erodes with distance more rapidly for properties close to good over-capacity schools than it does for those close to good under-capacity schools.

performing schools. In this model the existence of admissions constraints acts to restrict the supply of school quality such that perceived school quality erodes more rapidly with distance if the school is over-capacity than if under capacity (solid lines compared to dotted lines).

The lower Figure shows the differing predictions of the popularity hypothesis. Here, as before, one obtains a steeper gradient between perceived quality and school test score performance for lower distance to school residences (solid lines compared to dotted lines). But now, admissions constraints act to increase the rate at which perceived quality increases with test score performance, so the gradients are steeper for capacity-constrained schools. These Figures make it evident that there are testable empirical predictions that emerge from these two theoretical approaches, with different signed interactions between performance and distance emerging in school quality functions.

### 3). Congestion

In addition to supply constraints and school popularity, there is a third possible link between over-capacity schools and house prices. It may actually be that over-capacity schools suffer from problems associated with overcrowding, congestion and higher pupil-teacher ratios, and this may have direct effects on parental willingness to pay for schooling. In this case we would expect under-capacity schools to be in higher demand, implying higher local house prices nearer capacity unconstrained schools. In this congestion model, the effect of this would be to shift the curves for over-capacity schools in downwards, relative to the curves for under-capacity schools, thus predicting the opposite from the supply constraint and school popularity models.

## Empirical Implications

Clearly, it is not possible, *a priori*, to use theory alone to predict quite how performance, school distance and school admissions constraints will influence parental demand, so this is question that must be addressed empirically. We assume that the school quality function  $q(s, d, \sigma)$  defined above is the object of parental preference over schooling choices, and that this can be estimated by revealed preference methods in a hedonic property value framework. Property prices trace out the function  $q(s, d, \sigma)$ , once other factors that affect housing demand are held constant. There is, of course, a large literature looking at willingness to pay in a hedonic price setting, but the work looking at paying for schools uses a less general quality function  $q(s)$ . The distinguishing feature of our work here is to consider the more general quality function that additionally incorporates  $d$  and  $\sigma$ . This, we believe, enables us to say a lot more about the source of house price premia associated with primary schooling.

Note that our first supply-constraint hypothesis implies that the premium on home prices paid for school performance decays more rapidly for over-capacity schools than under-capacity schools. But importantly, for properties *very close* to schools there should be no difference in the performance premium between under-capacity and capacity-constrained schools. If this were not the case, rational home buyers would always choose properties close to under-capacity schools, where the marginal cost of performance is lower.<sup>6</sup> In empirical terms there should be no interaction in a hedonic

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<sup>6</sup> This assumes that parents can choose from the full set of schools. In practice, such choices may be limited. Our data shows that the over-capacity schools are concentrated in the inner metropolitan areas, whereas under-capacity schools are more dispersed.

pricing model between  $s$  and  $\sigma$  at zero distance and the decay should be picked up by a negative  $s*\sigma*d$  interaction.

Conversely, if the second hypothesis, school popularity, is correct, the price of performance is higher in over-capacity schools than in under-capacity schools, at any school-residence distance. Thus there should be a negative  $s*\sigma$  interaction (i.e. even at zero distance, and actually at any distance so  $s*\sigma*d$  should be unimportant). Finally, the congestion model predicts local house prices near capacity constrained schools to be lower than those near schools with spare places and so there should be a negative association between house prices and the presence of admission constraints.

### **3 Methods and Data**

#### **Data sources**

Our data source for house prices and housing characteristics is the Nationwide Building Society's survey, which is based on all property sales in Great Britain for which the building society makes mortgage loans. We have the data from 1995-2002. The size of the sample varies considerably from year to year, with the size of the market and the size of the lender's share. We restrict attention to properties in the Metropolitan area of Greater London and its surroundings.

Our schools data comes from the Department of Education and Skills, and is made up from the Annual School Census from 1996-2001 and the publicly available school performance tables over the same period. The lead measure of school performance in these tables is the proportion of children reaching target levels (Level 4) in the standard

age-11 tests.<sup>7</sup> These annual performance table scores will be noisy measures of long run school performance, which we assume is parents' main choice objective. To improve on these single-year measures, we assign to each school in a given year the average of its annual scores in the current and all prior years.

We match each property to its nearest three primary schools (and three secondary schools, and nearest private school), using Euclidian distances derived from property and school grid references. These grid references are assigned on the basis of mailing address postcodes<sup>8</sup> using Ordnance Survey Codepoint<sup>TM</sup> data.<sup>9</sup> We also include some area characteristics. Firstly, the Nationwide housing database provides indicators of neighbourhood conditions based on the Acorn classification system created by CACI marketing.<sup>10</sup> In addition, we match in dwelling density estimates from the 2001 Census, based on address postcode. All school characteristics are matched to property transactions occurring in the *following* year, so our database of property transactions covers 5 years from 1997-2001, plus the first quarter of 2002.

We use two samples: The full sample for the London and surrounding area, and a sub-sample restricted to properties close to Local Education Authority boundaries in London (for reasons which will become clear in due course when we more fully discuss our modelling strategy). Sample characteristics are shown in Table 1. The average distance between primary schools and residences in our main sample is just 560 metres. Average annual performance is 68 per cent over these years, meaning that 68 per cent of children reached the target grade between 1996 and 2000. In fact this average masks

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<sup>7</sup> These tests are known as the 'Key Stage 2' tests, as they correspond to the end of Key Stage 2 in the National Curriculum for primary school children.

<sup>8</sup> A residential postcode is, typically, shared by 10-15 houses on one side of a residential street.

<sup>9</sup> 'Code Point' provides a National Grid reference for each unit postcode in Great Britain.

<sup>10</sup> CACI is the UK subsidiary of CACI International Inc. and provides marketing and related information systems, including the customer profiling product known as ACORN. ACORN provides geodemographic classifications for postcodes throughout the UK. We utilise those codes that indicate postcode sectors (approx 3000 households) that contain high proportions of social housing.



substantial increases over time, with the proportion now averaging nearly 80 per cent. There are a higher proportion of admissions constrained schools in the London LEA border sub-sample, but average performance and school distance is lower.

### Matching schools to properties

Since a child at a given dwelling potentially has access to a number of schools, we need some way of linking schools to dwellings according to the probability of a child living in a particular place gaining admission. We do this on the basis of how close each school is to each property. For each property in our data set, we define a *local school cluster* as the set of three nearest primary schools. We define the *school performance* available to a particular dwelling  $i$  at time  $t$  as the inverse-distance weighted average of the performance of these nearest three schools  $j$ :

$$s_i = \frac{\sum_{j \in J} \tilde{d}_{ij}^{-1} \tilde{s}_j}{\sum_{j \in J} \tilde{d}_{ij}^{-1}} \quad (1)$$

where  $J$  is the set of nearest three schools to  $i$ ,  $\tilde{s}_j$  is the school-specific performance measure and  $\tilde{d}_{ij}$  is the school-property specific distance. The effective school-distance for a given dwelling is calculated as the harmonic mean of the nearest three schools, which is the natural measure given the inverse-distance weighting. So the *school-distance* measure is

$$d_i = \left( \sum_j \frac{1}{J} \frac{1}{\tilde{d}_{ij}} \right)^{-1} \quad (2)$$

where  $J = 3$  in our case. Thus a property that is adjacent to one school, but further away from others, will be assigned the school performance of the adjacent school, and a

distance of zero. A property that is equidistant from three schools is assigned the arithmetic-mean performance of the nearest three, and the common distance. Any dwellings that have a school-distance greater than 1km are dropped from our estimation sample, since they are unlikely to be relevant when considering school choice issues.<sup>11</sup> This is certainly true for primary schools, on which we focus here, although some children do travel long distances to attend secondary schools, which, on average, are much larger in terms of student numbers.

### **School admissions constraints**

As our theoretical discussion has emphasised, we want to understand how admissions constraints influence the demand for schooling. To do this, we need some measure of the extent to which schools are likely to be oversubscribed or undersubscribed when parents make applications for admission. Applications are made about one year prior to entry, usually to the Local Education Authority, although some church schools manage their own admissions. Information on actual applications relative to pupil places would seem the obvious choice, though there are problems. Firstly, the information is not easily obtained – either by us, or by parents making their school choices. Secondly, a measure of over-subscription would be highly endogenous in the house price models we intend to estimate: school quality improvements lead to a simultaneous increase in demand for places and local housing.

Instead we look for a measure of the extent to which a school is admissions-constrained, based on pre-determined variables in our schools data set. The variable we use is an under-capacity index. It seems reasonable to assume that parents will expect a

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<sup>11</sup> This loses 17% of the total available sample. However, the results are similar, whether or not we restrict the sample in this way.

more competitive admissions environment around over-capacity schools, with more prospective pupils chasing fewer places. This is first and foremost because schools become full through the level of applications relative to pupil places in previous years, which are presumably indicative of the demand parents can anticipate in the current year. But it is also because schools that become under-capacity through pupil losses are more likely to be able to admit unsuccessful applicant pupils in subsequent terms or years. It is not uncommon for parents to make temporary schooling arrangements until they can gain entry into their preferred school.

As the basis for this index, we utilise a capacity measure that is available in our schools data from the UK Department of Education and Skills. In primary schools, the number of classroom spaces is used to determine this capacity measure. Unfortunately, this variable is available for only one year (2001), but it seems reasonable to treat it as fixed over time for the duration of our sample, since changes in school physical infrastructure are relatively rare.

Over the period of spanned by our data, admissions numbers were determined at LEA level by a ‘standard number’ for each school which was set in the early 1990s and was only subject to change under special conditions like buildings improvements. Although we do not have information on this ‘standard number’, we know that physical school capacity was an important component in the way it was set and adjusted. So we assume that the ratio of pupils to capacity in any year is a reasonable measure of the extent to which schools are over-capacity, and hence likely to be admissions-constrained in the following year. So, for each school we calculate the ratio of full time pupils to capacity, and use this to construct an index of the extent to which schools surrounding a particular residential location are free from constraints in terms of their ability to admit pupils. To be more precise, in our empirical work the variable  $\sigma$  in the

local school quality function  $q(s, d, \sigma)$  is defined as  $\{1 - (\text{full time equivalent pupils}) / (\text{school capacity})\}$ .<sup>12</sup> Clearly, the higher this index for a given location, the less likely it is that admissions to neighbouring schools are constrained by physical capacity.

### Empirical model

Putting together the theoretical reasoning of Section 0 with the information described above into an empirical model of house price determination leads us to the following empirical specification:

$$\ln p_{it} = q(s_{it-1}, d_i, \sigma_{it-1}; \gamma) + \mathbf{x}'_{it} \boldsymbol{\beta} + f_s + \varepsilon_{it} \quad (3)$$

where  $p_{it}$  is the price of property in postcode unit  $i$  at time  $t$ ,  $q$  is postcode-unit-specific expected school quality which is a function of:  $s_{it-1}$ , the postcode-unit-specific measure of performance in the local school cluster in the previous period;  $d_i$ , the postcode-unit-specific school-distance defined above; and  $\sigma_{it-1}$ , the indicator of whether the local school cluster is capacity-constrained. In (3)  $\mathbf{x}_{it}$  is a vector of other observable characteristics,  $\varepsilon_{it}$  is the usual random error term and we allow for unobserved spatial fixed effects,  $f_s$ , related to the school cluster  $s$ . Again it is worth comparing our more general approach with what is typically looked at in the literature, where the  $q$  function incorporates only test score performance and not distance and/or capacity.

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<sup>12</sup> Where the ratio of pupils to capacity at any location is an inverse-distance weighted average of this ratio in the nearest three schools.

## Area effects on school performance

Any study of the effects of schools on house prices must take account of general neighbourhood factors. Anything desirable about the neighbourhood – local amenities, community attributes, or housing quality – will drive up local prices. In a world of imperfect capital markets, the rich outbid the poor for desirable neighbourhoods [e.g. Benabou (1996), Epple and Romano (2000)]. If children from richer backgrounds do better at school, then observed school quality is better in richer neighbourhoods. School performance and house prices are simultaneously determined, and regression estimates that do not take this sorting into account are biased.

Work on school price effects has tried to get round this via a number of identification strategies. These include: specifying an extensive range of neighbourhood attributes in the property value regression [Downes and Zabel (2002)]; looking at differences between neighbouring properties in different school attendance districts [Black (1999), Gibbons and Machin (2003)], exploring what happens when school district boundaries are redrawn [Bogart and Cromwell (2001)]; or using semi-parametric methods to eliminate general spatial variation [Gibbons and Machin (2003)].

Here we use a combination of approaches, but our main device is to specify *school-cluster* fixed effects in our regressions. Persistent effects common to all properties in the school cluster can be accounted for in our property price regressions by a standard fixed-effects strategy, using observations in the same 3-school-cluster to calculate the fixed effects. In our setup, an observation is assigned to a school cluster with other observations that share the same nearest, second nearest and third nearest primary school. Observations in the same group can be property transactions from the same postcode in different periods, or from different postcodes in the same or other

periods.

This school-cluster fixed effect approach is illustrated in Figure 2, which maps three schools (indicated by  $\Delta$ ) in Haringey, North London and the corresponding residential postcode centroids in the related schools clusters. The postcode centroids are shaded to indicate the school cluster to which they belong. Dwellings in Cluster 1 have the upper right-hand school as the nearest, the lower left-hand school as the second nearest and the lower right-hand school as the third nearest. Cluster 2 has the lower left-hand school as the nearest, the upper right hand school as the second nearest, and the lower right-hand school as the third nearest. It is left to the reader to deduce the rest. Each cluster is treated as a fixed effect in our regressions.

The point of this strategy is to remove as much cross-sectional variation as possible<sup>13</sup>, whilst retaining the scope for measuring residence-school distance effects. Indeed much of the identification in our model comes from differences in the time trends of school-cluster performance. But not all: Some cross-sectional variation remains between properties within 3-school-clusters. This is because each residence has a unique residence-school distance vector, and so offers a unique supply of school-quality within the cluster.<sup>14</sup> Residence-school distance effects are identified here because each 3-school cluster has a different mix of properties in each year, so the mean residence-school distance is not constant over time.

Our second approach for eliminating area effects is to transform (3) into a spatially differenced model that eliminates area fixed effects. For any characteristic  $x_i$  associated with dwelling  $i$ , we calculate the characteristic  $x_j$  of a geographically

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<sup>13</sup> An alternative approach would be to use repeated observations of sales in the same postcode unit. This would result in a serious loss of data and information, since the sample of repeated postcodes is quite small, and would make it impossible for us to measure distance effects.

<sup>14</sup> In practice we can eliminate this variation in performance, with little effect on the performance results, by using simple means rather than spatially weighted means.

‘neighbouring’ dwelling  $j$ , and work with the spatially differenced variable  $x_i - x_j$  in our regressions. This eliminates any neighbourhood effects that are common to both dwellings. But the transformation will also eliminate any differences in school performance unless we make efforts to ensure that our neighbouring dwellings have access to different schools. If we had clearly defined neighbourhood catchment area boundaries, we could focus on dwellings that are neighbouring, but in different catchment areas [as in Black (1999)]. Since the only ‘catchment area’ boundaries that can be reliably observed are the boundaries corresponding to the districts for the admissions authorities – the Local Education Authorities in England – we use differences between matched pairs of dwellings that are ‘neighbouring’, but in different LEAs. Each dwelling is matched to its nearest neighbour in an adjacent LEA and we restrict the sample to ensure that all neighbours are within some specified distance of each other.<sup>15</sup> illustrates the London sample of dwellings within 1km of the nearest dwelling across the LEA border. Estimation is based on cross-LEA border differences in prices and characteristics within these thin boundary zones.

## 4 Results

### Performance, distance, and prices

Our empirical results are derived from statistical regression estimates of the house price model in equation (3) under alternative specifications. The main focus is on the estimation of the function  $q(s, d, \sigma)$ , which we parameterise as a simple linear function

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<sup>15</sup> We match the nearest property in the same year.

of  $s$ ,  $d$ , and  $\sigma$  with interaction terms, and we make strong efforts to deal with the potential endogeneity of school performance using the strategies laid out in Section 0.

The central results relating to our hypotheses about distance and admissions constraints are in Table 2 and 3. We look first at distance and performance effects only in Table 2, where the school quality function  $q(s,d,\sigma)$  is parameterised as a linear<sup>16</sup> function of distance, performance and a distance-performance interaction (at this juncture we assume capacity  $\sigma$  has no effect). In all cases, the sample is restricted to properties that are within 1km of a primary school, since we regard households living outside this range as unconcerned with primary school performance issues.<sup>17</sup>

The basic effect of school performance is in Row 1. This should be interpreted as the effect of school performance on a property at the school gate (zero distance). Column (a) is a property value model with a full set of property controls, area characteristics (as specified in the Appendix), time effects, and Local Education Authority dummy variables. In this specification the impact on house prices is large – up to 5.4 per cent for a 10 percentage point shift in school performance.<sup>18</sup> This is close to the largest results we reported for English primary schools in Gibbons and Machin (2003) and is similar to Black’s (1999) analysis of US elementary schools. However, controlling for unobserved neighbourhood factors through school-cluster fixed effects in Column (b) almost halves the effect. Now, the main effect of performance is 3.0 per cent on prices for each 10 percentage-point improvement in the proportion of children reaching the target test grade. This is almost exactly in line with our previous results for the South East of England, using a different source of aggregated house price data and a

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<sup>16</sup> Prior experimentation suggests that non-linearities in distance or performance are not statistically important.

<sup>17</sup> It would be a different story for secondary schools where children regularly travel further distances to school.

<sup>18</sup> Calculated as  $[\exp(0.528 \times 0.1) - 1] \times 100$ .



very different cross-sectional specification.<sup>19</sup> We consider the fixed effect estimate of Column (b) to be a more robust estimate of the parameter, and the Column (a) estimate without school-cluster fixed effects to be upward biased by unobserved neighbourhood effects.

Consider now the effect of school distance and its interaction with performance. Again, the estimates without school-cluster fixed effects in Column (a) are questionable. Firstly, the main effect of school distance is positive (Row 2) and the coefficient on the interaction of distance and performance is low and not statistically significant, which implies: i) that the performance in the nearest-school cluster has a constant effect on the price of neighbouring properties, regardless of their distance to the school and ii) that house prices decrease with distance, even from the best schools. This is hard to square with our theoretical discussion in Section 0, or with anecdotal evidence.

Using the school-cluster fixed effects model in Column (b) we obtain more plausible results. Again, the main effect of distance from low-performing schools is positive: prices rise by about 1.9 per cent per 100m distance from a school with an implied zero performance score. However, the significant distance-performance interaction term in Row 3 implies that this negative school impact is ameliorated by school performance: for schools with 79 per cent<sup>20</sup> and more of their pupils attaining the target grade. This represents the 90<sup>th</sup> percentile in the long-run performance distribution. Above this, the distance effect switches sign. This shows that people pay to move close to schools at the top of the attainment distribution. The interaction term also means that distance from a school reduces the school performance premium. As we would expect, the performance of nearest schools matters less for prices of properties that are furthest

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<sup>19</sup> From Table 2, Column (2) in Gibbons and Machin (2003) the estimate is 2.9% for a 10 percentage point improvement.

<sup>20</sup> The marginal effect of distance is  $0.0194 - 0.0245 \times s$ . Setting to zero and solving for  $s$  gives this result.

away, each 100 metres reducing the house price performance premium by around 8.4 per cent of its initial value.<sup>21</sup>

In the Column (c) specification, instrumenting school performance with salient school characteristics<sup>22</sup> results in slightly bigger coefficients on performance, but the general pattern of interactions is unchanged and re-confirms the findings. Increased coefficient estimates using Instrumental Variable methods is what we observed in our earlier work [Gibbons and Machin (2003)]. Our interpretation then, and now, is that year-on-year or even time-averaged performance measures are less than perfect indicators of perceived long-run school performance and introduce a form of measurement error. Instrumenting with more stable school characteristics corrects for this attenuation bias due to measurement error.<sup>23</sup> Note though, that the IV performance coefficient in Column (c) is not statistically significantly different from the estimate in Column (b) using the standard Hausman test ( $p$ -value = 0.232).

The school-cluster fixed effect approach provides a strong test of the existence of school effects on prices. However, our assignment of dwellings to schools is based on proximity and we would like more certainty about the choice of schools available to residents of each dwelling. To do this perfectly, we would need clearly defined, mutually exclusive catchment areas. As discussed in earlier sections, we can use Local Education Authority boundaries to stand in for catchment area boundaries for dwellings close to the LEA borders. In practice, this means transforming the regressions to use differences in the variables between nearest-neighbour dwellings on either side of an

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<sup>21</sup> Because each 100m step reduces the premium by roughly  $0.0245/0.2914 = 8.4\%$  relative to the zero-distance premium

<sup>22</sup> As instruments we use indicators of the institutional age range (with nursery, junior years only), church-school status, and 'beacon' school status, all interacted with distance. A 'beacon' school is a school designated by the Department of Education and Skills as exhibiting high teaching standards and models of good practice.

<sup>23</sup> We have further evidence for this interpretation, in that our estimates of the performance premium are some 50% lower if we use annual, rather than time-averaged school performance measures.

LEA boundary. Column (d) uses these cross-border differences to identify the effects of access to different schools in a similar way to Black (1999), Bogart and Cromwell (1997, 2001), and Gibbons and Machin (2003).

The sample in Column (d) is much smaller and less representative than the sample used in Columns (a)-(c) because we restrict to properties that are within 1km of the nearest on the other side of a LEA boundary. Consequently, we might expect some differences in the estimates. Nevertheless, the patterns in Column (d) are broadly similar to those derived from the school-cluster fixed effects in Column (b), though the distance effects are less severe: School performance exerts a positive impact on prices that significantly decreases with distance from the school; prices rise with distance from the school at lower performance levels, but the price-distance gradient is inverted for the highest performing schools. Overall, the evidence from this alternative cross-border approach backs up what we have found already.

### **...with admissions constraints**

In Table 3 we incorporate admissions constraints into the statistical within-cluster and cross-border models. First, in Column (a) and (b), we include our index indicating the degree to which schools are under-capacity. In (c) and (d) we interact this with the distance and performance variables. Structured this way, the results first explore whether schools that are under-capacity are, on average, valued any more or less than those that are over-capacity. If under-capacity schools are valued because they are less congested (or congestion model of Section 2), we would expect under-capacity schools to attract higher house prices. The fully interactive models in (c) and (d) then enable us to distinguish more fully between the competing models of primary school choice

introduced in Section 2 above. To interpret the coefficients, note that the definition of the capacity index means that the main effects of performance, distance and their interactions in Rows 1-3 relate to schools that are just at full capacity (pupils/capacity = 1, so our index of under capacity =0).

In the Column (a) and (b) specification the estimated coefficient on the under capacity variable is negative, but small and never statistically significant, showing no direct effect from admissions constraints on house prices. This is consistent with our popularity and congestion models, which predict interactions between admissions constraints and performance or between admissions constraints and distance, but make no predictions about a direct effect from admissions constraints. It is *not* consistent with a congestion story, where we would expect over-crowding to depress local house prices throughout the performance and distance distribution.

However, to properly consider which of the theoretical models is best in line with the data we need to estimate the interactive model including interactions between capacity, school performance and distance. These estimates are shown in Columns (c) and (d) where there are significant interactions between admissions constraints and the effects of performance and distance.<sup>24</sup> Since the coefficients are not straightforward to interpret, and to link back to the theoretical discussion, we illustrate our estimates diagrammatically in Figures 3a and 3b. These Figures are based on all the coefficients in the full-sample estimates in Column (c) and the price is expressed in terms of proportional differences from the mid-range admissions-unconstrained school.

Figure 3a exhibits the hedonic price function of distance, by six, school-performance and admissions-constraint categories. The pupil/capacity ratio is set to one-

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<sup>24</sup> Viable instruments are not available for all the performance-distance and performance-capacity interactions in these models. So we simply register that, in the light of our earlier IV estimates, the performance effects and their interactions with distance and capacity may be under-estimated.

standard deviation (0.121) above unity to represent admissions-constrained, over-capacity schools, and one standard deviation below for under-capacity schools. So the graphs (and following discussion) delineate schools that are 12.1 per cent over capacity and 12.1 per cent under capacity. The categories in Figure 3a are:

- i) Mid-performing schools (65 per cent), over-capacity (*65 per cent\_over*)
- ii) Mid-performing schools (65 per cent), over-capacity (*65 per cent\_under*)
- iii) High performing schools (100 per cent), over-capacity (*100 per cent\_over*)
- iv) High performing schools (100 per cent), over-capacity (*100 per cent\_under*)
- v) Low-performance schools (30 per cent), over-capacity (*30 per cent\_over*)
- vi) Low-performance schools (30 per cent), over-capacity (*30 per cent\_under*)

The vertical ordering of the solid lines in Figure 3a shows clearly the main effect of school performance on prices, at any distance within the 1km limits of the sample, with prices of dwellings adjacent to over-capacity, top performing schools some 26 per cent higher than those adjacent to the worst performers<sup>25</sup>. Another clear feature from Figure 3a is that schools of low and mid-range performance are *not* regarded as positive neighbourhood amenities: prices actually rise as we move away from such schools (e.g. along the *65 per cent\_over* or *65 per cent\_under* lines). But, as we observed before in Table 2, the interaction between distance and performance has strong effects (Table 3, Row 3) resulting in the converging line pattern in Figure 3a. As a consequence, the *very best* schools (the top 10 per cent in the long-run performance distribution) pull up prices of dwellings within their immediate vicinity relative to those further away (e.g. along the *100 per cent\_over* or *100 per cent\_under* lines in Figure 3a).

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<sup>25</sup> Taking 70% as the performance gap, we calculate the price difference for highly admissions-constrained schools as  $\exp(0.70 \times 0.300 + 0.70 \times 0.12 \times 0.254) = 0.260$ , where 0.70 is the performance gap and 0.12 is 1 standard deviation in the over-capacity index.

Focussing now on the role of admissions constraints, the important thing to note is the weakness of the interactions between capacity and distance, or between capacity, distance and performance, in Rows 6 and 7 of Table 3. This means that admissions-constraints have little or no influence of the way that the price of a dwelling changes with distance from neighbouring schools. So, looking at Figure 3a we see that the premium associated with high-performing, over-capacity schools (*100 per cent\_over*) declines slightly faster with distance than does the premium for high-performing, under-capacity schools (*100 per cent\_under*). But the difference is barely detectable, and, from Table 3, not statistically significant.

Although admissions constraints seem to have no impact on the rate at which prices change with distance, they do change the implicit price of performance at any distance. This is seen more clearly in Figure 3b which shows the hedonic price function of performance, for four school types:

- i) Over-capacity, and immediately adjacent to the dwelling (*0m\_over*)
- ii) Under-capacity, and immediately adjacent to the dwelling (*0m\_under*)
- iii) Over-capacity at mean residence-school distance of 560m (*560m\_over*)
- iv) Under-capacity at mean residence-school distance of 560m (*560m\_under*)

Firstly, observe that performance in under-capacity schools attracts a much *lower* premium than performance in over-capacity schools (from Table 3, Row 5). In fact, the premium for a 10 percentage-point improvement in school quality at zero distance from over-capacity schools is 26 per cent higher than that for under-capacity schools: 3.4 per cent as against 2.7 per cent.<sup>26</sup> So, in Figure 3b, the slope of the performance-price function for under-capacity schools in Figure 3b is less steep (*0m\_under* compared to *0m\_over*). This has quite substantial financial implications. At current prices, parents

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<sup>26</sup> Calculated as  $\exp\{0.10 \times 0.300 + 0.10 \times 0.12 \times 0.254\} - 1 = 0.034$  and  $\exp\{0.1 \times (0.300 - 0.10 \times 0.12 \times 0.254)\} - 1 = 0.027$  from Row 1 and Row 5 in Column (c), where 0.12 is a 1 s.d. shift in the over-capacity index.

can expect a move from an average dwelling outside a weak school, to one outside a top over-subscribed school, to cost around £61000 (26 per cent of the mean property price in London and the South East in Apr-Jun 2004). A similar move to an undersubscribed top school would cost, on average, about £49000 – some £12000 less!

As we saw in Figure 3a, the performance premium declines as we move from zero-distance to mean-distance schools, but the differential between admissions-constrained and unconstrained schools persists (*560m\_under* compared to *560m\_over*). Again, as we observed before, households pay lower prices for properties close to primary schools, *unless* schools succeed in getting over 80 per cent of their pupils up to the target grades.

Column (d) presents comparable estimates for the London LEA border sample, using cross-LEA border differences. We do not illustrate this specification diagrammatically, but it is clear from the coefficients that the patterns are similar, with shallower price-distance gradients, but more pronounced impacts from admissions-constraints. The performance premium some 40 per cent greater than in admissions-unconstrained schools (3.1 per cent for a 10 percentage point performance improvement in admissions-constrained schools, compared to 2.2 per cent in others<sup>27</sup>).

## **Interpretation and discussion**

The reported results reveal a number of features of the house price-school performance relation. First, in line with other studies [like Black (1999) and Gibbons and Machin (2003) for primary schools, and Leech and Campos (2003) and Rosenthal (2003) for

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<sup>27</sup> Calculated as  $\exp\{0.10 \times 0.259 + 0.10 \times 0.12 \times 0.357\} - 1 = 0.031$  and  $\exp\{0.10 \times (0.259 - 0.10 \times 0.12 \times 0.357)\} - 1 = 0.022$  from Row 1 and Row 5 in Column (c), where 0.12 is a 1 s.d. shift in the over-capacity index.

secondary schools] higher test score based school performance is associated with increased property prices. However, we find it is only the best one-in-ten schools that generate higher than average prices close-by. Second, there are important interactions between performance and residence-school distance and school capacity that induce systematic variations in the house price premium associated with better neighbourhood primary schools. Third, the nature of these interactions can enable us to discriminate between different theoretical reasons as to why parents are prepared to pay higher prices for living in an area that will enable to get their children admitted to a particular school.

So how are we to interpret the results in the light of our earlier theoretical discussion? The first point is that there is little evidence for a *congestion* model in which demand for over-capacity schools is low. This would imply rising local house prices in neighbourhoods in which schools are becoming less crowded, which is not what we observe. In actual fact, our under-capacity variable is generally weakly negatively related to house prices in the statistical models and the only place where even an inkling of congestion effects can be seen is from the fully interacted model at the very bottom of the school performance distribution. In Figure 4 (b) one can see this for lower levels of performance where the over and under capacity lines cross, and over-capacity schools attract lower prices than those that are under-capacity. The crossover-point on the graph in Figure 4b is at a long-run average Key Stage 2 performance level of 41 per cent, which is the 5th percentile of the long-run performance distribution. Even below this the lines are not very far apart at all, so we can almost certainly rule out the possibility of congestion effects in all but the worst-performing schools.

This leaves the two hypotheses which assert that there is a higher house price premium for admissions-constrained schools. But these differ in the way that performance interacts with distance and capacity constraints. There are two key points



to note here. First, the performance premium is higher for admissions-constrained schools even at zero distance to the school. Second, note also that admissions-constraints have almost *no* impact on the rate at which prices change with school distance. Thus, in line with the discussion in Section 0, the results are supportive of our *popularity* hypothesis – there are complementarities between the signal provided by a schools being full and the performance of the school measured in standard pupil tests.

On the contrary, we find no evidence that our *supply-constraint* hypothesis is correct: there is no premium to be paid for moving closer to an admissions-constrained school. This comparison is most easily made by looking at the Figures, which are the empirical analogues to the theoretical models presented in Section 2. Comparing Figure 3a in conjunction with Figure 1a, and Figure 3b in conjunction with Figure 1b, makes it evident that the evidence is in line with the predictions of the school popularity model, rather than the model based upon supply constraints.

### **Is this not just unobserved school quality?**

Our claim then is that admissions constraints influence the process of school and residential choice, not by forcing parents to move much closer to full schools to increase the chances of admission, but by signalling popularity and encouraging demand. Admissions constraints have somewhat unexpected effects on the process of school choice. An alternative interpretation is that over-capacity, admissions-constrained schools are simply better quality schools in way that is observable to parents but unobserved to us. Under this scenario, admissions constraints do not influence school choice decisions. Instead, better schools – that is better in ways that are not represented fully by our test score performance measure – push up property prices and become over-

capacity through popularity. This would change the interpretation of our results only slightly. The interaction between performance ratings and under-capacity would, under this scenario, still show that popular schools that are good league-table performers attract higher prices than less-popular schools of a similar standard. But the popularity is attributable to desirable school attributes that are complementary to test-score performance.

Whilst this is a plausible position, further analysis makes it seem untenable. Table 4 presents the model of Table 3, Column (c) with additional controls for a number of possible performance-complementary school attributes. Column (a) includes the actual pupil average point-scores on the age-10/11 tests (rather than the proportion reaching the target level), and the point scores in age-6/7 tests. Column (b) replaces this with a measure of the educational ‘value-added’ that parents could expect the primary schools in the sample to impart to their children. This is calculated as the difference between the age-10/11 and age-6/7 pupil point-scores for pupils who eventually left the primary phase in 2002 and 2003 (the only years for which we have both tests for the same cohorts). Column (c) includes all the above, plus indicators of other salient school characteristics like age structure, designation by the Department of Education and Skills as a high-standard ‘beacon’ school, and the number of qualified teachers. Finally in column (d) we simply model the capacity variable by a dummy indicating under-capacity. None of this makes much difference to the general pattern of results we observed in Table 3, and the performance-capacity interaction remains stable and statistically significant. If the performance-capacity interaction in the house price models really indicates some unobserved performance-complementary school attribute, then it is not a school-quality attribute that is easily recognised from amongst the list of usual suspects.

On this basis, we conjecture that league-table school performance has more of an impact on house prices when schools are over-capacity, simply because the over-capacity, admissions-constrained schools attract more attention. In principle, the popularity of a school provides information to prospective home buyers the quality of schooling they can expect, though in the case of primary phase education in the London area, this information does not seem to have much substantive content.

## **5 Conclusions**

This paper presents new estimates on the value of primary schooling for London and its wider metropolitan surroundings, based on property value models. We develop methodologies that are appropriate for the English setting where admission catchment areas are fuzzy and porous, and which take careful account of unobserved neighbourhood effects. Our results are largely based on changes in performance of schools over time, but also on highly localised variation in school performance within micro-geographic neighbourhoods. Our baseline results indicate a premium of around 3.0 per cent on prices for each 10 percentage point increase in the proportion of children reaching target grades in age-11 tests. This premium relates to a property notionally located outside the school gate.

Our first improvement on previous work is to present plausible estimates of the effects of school distance on this performance premium. Each 100m distance to a school erodes the performance premium by about 8.4 per cent relative to its initial level, so by 600m the premium is halved. We have also shown that all but the top 1-in-10 schools – judged on their long-run league-table performance – depress prices in their immediate

vicinity. Average schools are not desirable local amenities. This may, in part, be explained by ‘flight’ from the worst schools, but environmental problems also probably contribute. The morning and evening ‘school-run’ brings traffic and congestion, and there may be additional nuisances such as playground noise that deter buyers. These environmental effects and their negative impacts on prices have been noted and estimated before [Hendon (1973)].

We expected admissions constraints to have important effects on parental decisions over schooling, and indeed there are significant interactions between measures of school over-capacity and the premium paid for high performing schools. Our first *supply-constraint* hypothesis was that households will pay more to live ever closer to high-performing, over-capacity schools than under-capacity schools because school places are tightly rationed. This is not borne out by our data. Nor is the notion that *congestion* effects make over-subscribed schools less attractive to parents. A school that is admissions-constrained is worth more than one that is not, throughout most of the performance range and this impact is not sensitive to distance.

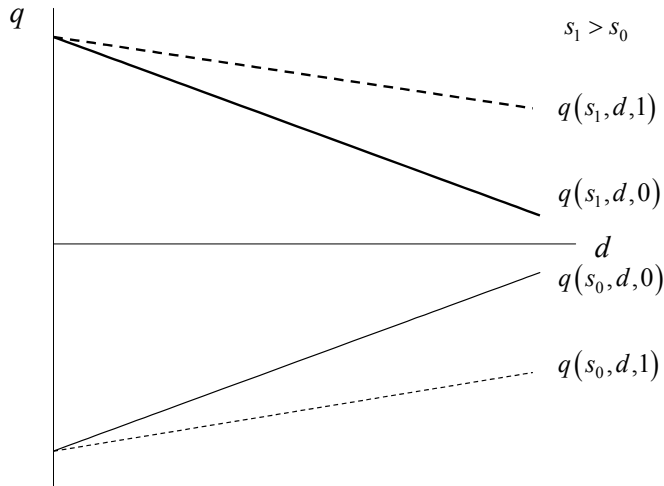
Instead, the empirical results are consistent with our *popularity* hypothesis in which parents believe, rightly or wrongly, that popular schools are better than under-capacity schools. This popularity effect might indicate that there are unobserved desirable school attributes that are complementary to league-table performance, yet we find it difficult to uncover any evidence of this. Thus there is a possibility of some degree of ‘herd’ behaviour in primary school choice, with the price not perfectly reflecting the fundamentals. Parents certainly do pay to get their children into better performing primary schools, but it is evident that they prefer popular, over-subscribed schools. This seems to be the case even if their league-table results may not be up-to-scratch at the time admissions applications are made by parents.

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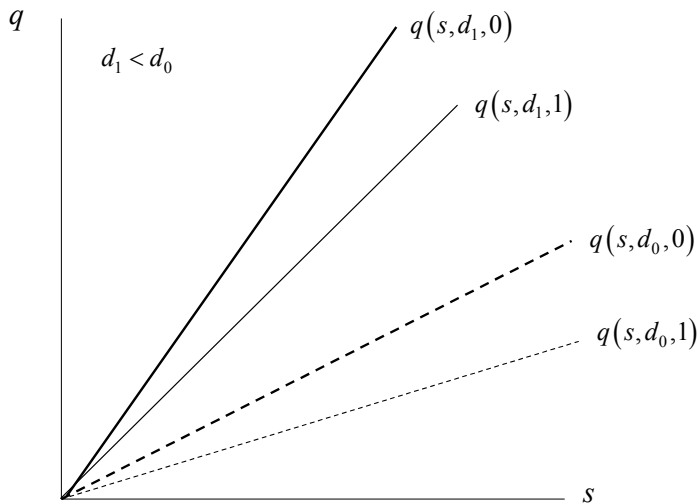
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**Figure 1 Conjectures about the Relationship Between Performance, Distance and Admissions Constraints**



*Supply constraint hypothesis: Admissions constraints constrain the supply of school quality*

Perceived school quality  $q$  declines with residence-school distance ( $d$ ) for good schools ( $s_1$ ) and increases with distance from bad schools ( $s_0$ ). With admissions constraints ( $\sigma = 0$ ) the rate at which perceived quality decreases (or increases) with distance is higher than without ( $\sigma = 1$ ). The probability of admission decreases more rapidly with distance than in under-capacity schools.



*Popularity hypothesis: Admissions constraints signal popularity and school quality*

Perceived school quality  $q$  increases with test score performance ( $s$ ). The slope is higher for low residence-school distances ( $d_1$ ) relative to high distances ( $d_0$ ). Admissions constraints ( $\sigma = 0$ ) increase the rate at which perceived quality increases with test score performance.

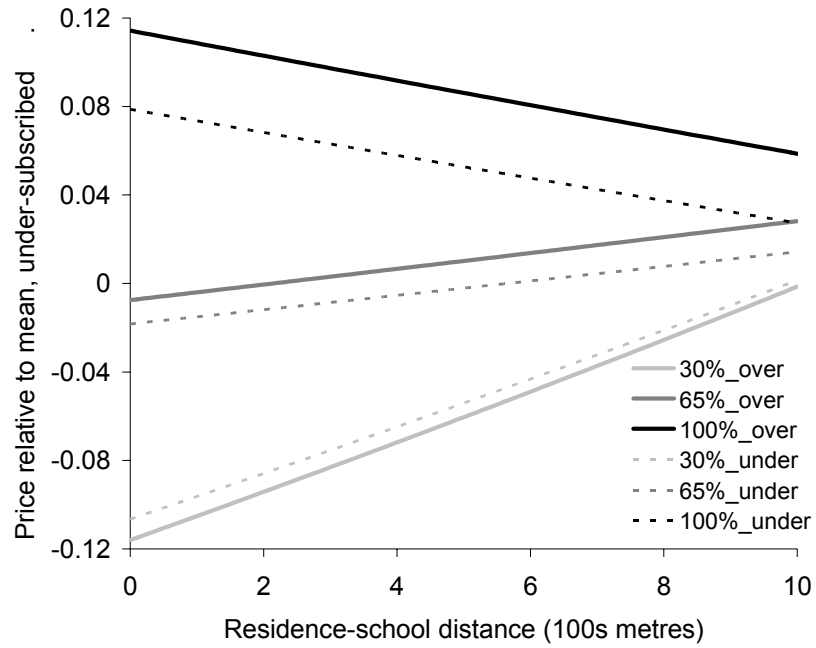




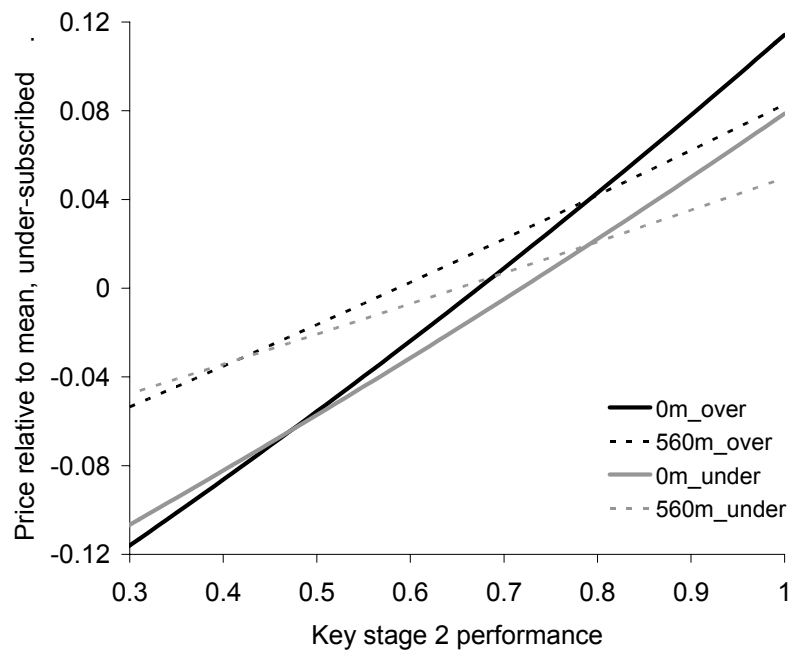
**Figure 3 Properties matched across Local Education Authority boundaries,  
London Only (1km Neighbours)**



**Figure 4: Estimated School-Price Functions**



(a) School distance effects on property price for low, mean and top performing schools, by admissions constrained status



(b) School performance effects on property price for properties at zero and mean school distance, by admissions constrained status

**Table 1 Key Summary Statistics**

	Mean	Standard Deviation.
<i>Full sample</i>		
Log-property price	11.569	0.505
Primary school performance (annual)	0.679	0.140
Primary school performance (time average)	0.638	0.129
Primary school distance (100m)	5.591	2.150
Admissions un-constrained schools (proportion)	0.585	0.493
Admissions unconstrained index	0.021	0.121
Sample size		106717
<i>London LEA boundary sub-sample</i>		
Log property price	11.688	0.515
Primary school performance (annual)	0.643	0.142
Primary school performance (time average)	0.601	0.127
Primary school distance (100m)	5.014	2.117
Admissions un-constrained schools (proportion)	0.431	0.496
Admissions unconstrained index	-0.018	0.119
Sample size		21065

## Notes:

Properties with prices above 1million are excluded from the Nationwide sample

Performance is the proportion reaching level 4 in Key Stage 2 tests at age 10/11

Full sample is for London and outer metropolitan area, restricted to properties with school-distance less than 1km

**Table 2 Performance and Distance Interactions**

	OLS	Within cluster	IV- Within cluster	X-boundary (1km)
	(a)	(b)	(c)	(d)
School performance	52.816 (15.04)	29.139 (14.06)	37.969 (4.92)	27.370 (8.62)
Distance (100s m)	0.493 (1.36)	1.943 (10.15)	2.759 (4.06)	1.216 (4.91)
Distance * performance	0.202 (0.38)	-2.449 (-8.63)	-3.679 (-3.59)	-1.772 (-4.56)
Area effects	52 LEA	14297 school	14297 school	London LEA borders
Sample size	106717	106717	106717	21065
R <sup>2</sup>	0.822	0.836	0.835	0.732

Notes: dependent variable is log property price

Sample restricted to properties with less than 1km school distance

Coefficients are x100

Performance and capacity measures in year t are derived from school-specific means of years 1 to t-1

Instruments for performance are beacon school status, church school status, age-range (nursery, junior only) and their interactions with school-distance

Mean inter-property distance in (f) is 500 metres, maximum 1km

**Table 3 Performance, Distance and Capacity Interactions**

	Within cluster (a)	X-boundary (1km) (b)	Within cluster (c)	X-boundary (1km) (d)
School performance	29.138 (14.05)	26.700 (8.31)	30.041 (14.20)	25.858 (8.27)
Distance (100s m)	1.943 (10.15)	1.216 (4.91)	1.885 (9.45)	1.175 (4.70)
Distance * performance	-2.449 (-8.63)	-1.761 (-4.53)	-2.408 (-8.16)	-1.701 (-4.36)
Under capacity index	-0.007 (-0.01)	-2.142 (-1.38)	12.006 (1.56)	-1.764 (-1.02)
School performance * under-capacity index	-	-	-25.416 (-2.22)	-35.703 (-3.13)
Distance * under-capacity index	-	-	-0.540 (-0.40)	-0.058 (-0.21)
Distance * performance, *under-capacity index	-	-	0.647 (0.32)	0.164 (-0.08)
Area effects	14297 school	London LEA borders	14297 school	London LEA borders
Sample size	106717	21065	106717	21065
R <sup>2</sup>	0.836	0.732	0.836	0.732

Notes: dependent variable is log property price

Sample restricted to properties with less than 1km school distance

Coefficients are x100

Performance and capacity measures in year t are derived from school-specific means of years 1 to t-1

Mean inter-property distance in (f) is 500 metres, maximum 1km

**Table 4 Robustness Checks (comparable to the specification in Table 3, column (3))**

	Model performance using test point scores and additionally include age 6/7 test scores (a)	Additionally include future value added in test scores (b)	Additionally include all test scores and other school attributes (c)	Model under-capacity as dummy variable (d)
School performance	27.911 (12.34)	30.164 (14.25)	27.248 (11.79)	32.560 (11.71)
Distance (100s m)	2.422 (8.12)	1.250 (3.95)	1.743 (4.80)	2.011 (6.85)
Distance * performance	-2.046 (-6.17)	-2.425 (-8.22)	-1.939 (-5.83)	-2.698 (-6.21)
Under capacity	12.129 (1.57)	11.502 (1.50)	0.101 (1.31)	2.485 (1.21)
School performance * under-capacity	-24.817 (-2.16)	-25.126 (-2.20)	-24.992 (-2.18)	-6.222 (-2.00)
Distance * under-capacity	0.566 (0.42)	0.621 (0.46)	-0.681 (-0.50)	-0.175 (-0.49)
Distance * performance, *under-capacity	0.601 (0.30)	0.595 (0.29)	0.388 (0.19)	0.507 (0.95)

Notes: dependent variable is log property price

Sample restricted to properties with less than 1km school distance

Coefficients are x100

League table performance and capacity measures in year t are derived from school-specific means of years 1 to t-1

Sample size 106717 with 14297 school cluster fixed effects.

## Appendix

### List of control variables used in the house price regression models

#### *School characteristics*

Inverse distance weighted proportion of non-ethnic minority children in nearest 3 primary schools  
Inverse distance weighted proportion with statements of special educational needs in nearest 3 primary schools  
Inverse distance weighted proportion with special educational needs (not 'statemented') in nearest 3 primary schools  
Inverse distance weighted average number of full-time children in nearest 3 primary schools  
Inverse distance weighted average proportion with 5GCSEs Grade A-C in nearest 3 private schools  
Inverse distance weighted average proportion with 5GCSEs Grade A-C in nearest 3 state secondary schools

#### *Dwelling characteristics*

Number of bedrooms  
Number of bathrooms  
Floor area in metres-squared  
Building age in years  
Property type (semi-detached) Detached, Terraced, Flat/Maisonette, Other  
Central heating (full), part, none  
Garage (none), single, double, parking space  
New/second-hand building indicator  
Freehold/leasehold

#### *Area characteristics*

Acorn group indicators for postcode sector populations that are predominantly council estate residents: better off, unemployed, greatest hardship  
Distance to nearest postcode represented in the sample (decile dummies)  
Census 2001 Output Area: number of dwellings per kilometre-squared (decile dummies)  
Local Education Authority dummies (not in school-cluster fixed effect models)

#### *Time periods*

Year – quarter dummies