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Capitalising the value of free schools : the impact of supply characteristics and uncertainty

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Capitalising the Value of Free Schools: The Impact of Supply Characteristics and Uncertainty

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Abstract

There has been a growing literature in both the US (for example Haurin and Brasington 1996, and Black 1999) and the UK (for example Gibbons & Machin, 2003) that estimates the way in which school quality is capitalised into house prices. Cheshire and Sheppard 1995 and 1999 estimated hedonic models in which the quality of the secondary school to which a household was assigned was a significant variable which provided evidence that secondary school quality was being capitalised into the price of houses.

In contrast Gibbons and Machin concluded that primary schools were more significant. Each of these analyses is predicated on the assumption that the value of local schools should be reflected in the value of houses. We argue here that this is rather too simple. We should expect variation in the capitalised price of a given school quality at either primary or secondary level according to the elasticity of supply of 'school quality' in the local market, the certainty with which that quality can be expected to be maintained over time and the suitability of the dwelling to accommodate children. These factors will vary systematically between and perhaps within cities. This paper explores the sources and the impact of such variations as well as the impact of model specification. The results provide new evidence on the complex and subtle ways in which housing markets capitalise the value of local public goods such as school quality and perhaps most importantly suggest that this is highly non-linear: houses in the catchment areas of only the best state schools command substantial premiums but such capitalised values can be very substantial indeed.

JEL: D12; H4; I2; R5

1. Introduction[1]

Concern over the quality of local schools, and over the variation in this quality, has drawn the attention of parents, policy makers and scholars. For many households, there is a single path to access quality education: identify an acceptable quality state-supported school and purchase a house in the area served by that school. Households lacking the means to move to such areas will face reduced educational opportunities, and that fact continues to generate concern.

Interest in these issues has a long history. For economists, it goes back at least to Tiebout (1956) and Oates (1969). The questions they addressed were how do we determine the demand for and supply of local public goods, including education, and how do we pay for such goods. It was Oates who first drew attention to the ways in which the value of local public goods were capitalised in urban land markets. From this many implications flow including the role that land markets play in articulating social segregation (see for example, Brueckner, Thisse and Zenou, (1999)) and the interaction this will have with the distribution of incomes (see for example Cheshire, Monastiriotis and Sheppard, (2000)) and the supply characteristics of local public goods and amenities. In this paper we explore the extent of capitalisation of educational quality into house prices, and examine how this might be affected by factors conditioning the supply of educational quality of a given expected standard as well as by local policies, such as land use planning.

At least four methodological approaches can be distinguished in the literature concerned with estimating the value placed on school quality. The longest established is a straightforward hedonic approach of which the two of the others are variants. The hedonic approach has some 80 years of evolutionary development behind it since agricultural economists first implemented it as a purely empirical technique to help identify the characteristics of vegetables commanding the highest price. Since Rosen's (1974) contribution it has become one of the standard techniques for analysing the price of complex goods, particularly that of housing.

Over the past 25 years a great many new insights have been gained as to the importance of model specification and the way in which the values of local neighbourhood characteristics, local public goods and locationally specific amenities are capitalised into land values. In parallel there have been important technical innovations in the effort to capture these effects more precisely. Perhaps the single most important lesson that has been learned is the most obvious: the value of any house varies systematically and substantially with its location and these location-specific factors are at

[1] We would like to thank the Leverhulme Foundation and the Lincoln Institute of Land Policy for supporting the work underlying this paper. We would also like to thank numerous colleagues, the referees and the Editor of this journal for valuable comments and insights. The usual disclaimer applies with respect to remaining errors.

least as important as the characteristics of the structure itself in determining market price. Sheppard (1999) provides a survey of recent developments in the hedonic modelling of housing markets.

Because there is no a priori basis on which to select the appropriate set of house and locational attributes to include and the relationship between market price and characteristics is typically non-linear, the specification of hedonic models is critical in determining the prices estimated for individual characteristics. Poorly specified models can yield misleading results. For example, the values of omitted locationally specific characteristics tend to be attributed to the estimated price of space, either internal space in the house or land area. Most of the value in the market price of urban land is in fact represented by the capitalised value of such locationally specific goods. These include the quality of local schools.

This may underlie the concerns that have led researchers recently to search for other ways of isolating the values attached to particular local public goods (or other spatially determined amenities). One alternative has been the 'natural experiment' (see Bogart and Cromwell, 2000) but because by their nature natural experiments are limited and not designed to answer specific questions, their use has to be opportunistic. In the case of Bogart and Cromwell although they can demonstrate that re-drawing school districts or catchment areas does indeed significantly affect local house prices (the loss of a neighbourhood school is estimated to reduce the value of the mean house price by some 10%) they cannot estimate the specific value attached to school quality. This is apparently because they had minimal variance in quality in the districts subject to revised boundaries: '...all the schools…are of high quality…'.

The other two methods deployed in the recent literature on the value of schools are essentially variants of hedonic analysis. Black (1999) sought to isolate the value placed on school quality by taking a large sample of house values for which she could reasonably argue that the only difference between them was the quality of the schools to which they gave access. In so far as this was correct then it followed that one could attribute differences in their value to differences in school quality.

This 'matched pair' method is really a type of hedonic analysis. It is implicitly admitted that many variables or attributes determine the price paid for the complex good, housing, and the researcher is simply trying to set up a situation in which the influence of all but one is eliminated. A difficulty with the approach is that there are no obvious tests to apply to see to what extent the research design has succeeded. In so far as there are omitted spatially fixed effects that are correlated with the school districts then there would be bias in the estimated value assigned to schools.

Gibbons and Machin (2003) develop another variant on hedonic analysis. They employ a kernel-based technique to offset for spatial fixed effects and exploit the co-variation in house prices and school performance within narrowly defined spatial units to reduce the need for a large set of covariates. They use mean house prices by area and deviations from means[2]. There are some potential problems with this approach. One relates to the characteristics of supply which, as is discussed below, will vary from city to city and under some circumstances, might vary systematically by location within cities. Thus the resulting estimates will be, at best, mean values for the whole area analysed (in the case of Gibbons and Machin, broad regions of England) and may conceal very large variation between individual cities. Indeed it is perfectly possible that in some cities primary school quality is more expensive whereas in others, secondary school quality is more expensive[3].

A second problem with this approach is really the same as the criticism of Black's matched pairs approach made above. While one may design the technique to control for spatially fixed effects – such as neighbourhood characteristics, other local public goods and specific locationally fixed amenities – we cannot test for the extent to which one has succeeded. Some of these locationally fixed effects are very local (for example views, access to local amenities, local disamenities from industrial land use, noise disturbance or the socio-economic characteristics of the neighbourhood). Since the catchment areas of primary schools are small, failure to separately account for spatially fixed effects will tend to be reflected in the value of the estimated parameter for primary school quality. Sorting processes in housing markets concentrate socio-economic groups whose children do better in the educational system in precisely the same areas, exacerbating the upward bias to the estimated value of primary school quality.

Because we have data for individual houses and because in our judgement a well constructed hedonic model can capture finer nuances and be used to investigate a wider range of possible influences we use a traditional hedonic approach and attempt to measure a wide range of local neighbourhood characteristics, including the socio-economic composition of the neighbourhood

[2] Two alternative estimation strategies are applied to a sub sample for Greater London where they have data for individual houses. Both give results close to their deviations from means technique including one which is a traditional hedonic model.

[3] Of course in extreme situations such flats might be bought simply to acquire an address within the catchment area of a particular school. Anecdotal evidence suggests that this does happen to a very limited extent but as the results reported below indicate there is a relationship between the suitability of a property to accommodate children and the capitalised value of school quality.

and other local public goods and localised amenities. We have also included the most fundamental of all features of the structure of urban land markets – land consumption and accessibility to jobs. This approach allows us to investigate the interaction between the physical characteristics of houses and their gardens with the capitalised values of local schools

2. The supply of quality and capitalisation into house values

One starting point for this study is the realisation that the economic and institutional structure within which educational opportunities are made available will naturally influence the extent to which school quality is capitalised in house prices. While the demand for school quality may not vary greatly from one city to another, at least within the same country, the implicit price may vary substantially because of variation in the characteristics of its supply which can vary substantially from one city to another. Where educational opportunities are at least in part determined by residential location, there are three central factors that are relevant in determining the supply of quality and the extent of capitalisation. These are the elasticity and nature of housing supply, the availability of substitute providers of education (other than the state-supported provider designated for the particular address), and the anticipated risk of variation in the quality of education provided. We discuss each of these factors in turn.

A. Housing Supply

An important source of variation in educational opportunity is the availability of housing suitable for accommodating children in the areas served by (better) quality schools. The responsiveness in housing supply, in turn, is determined by construction costs and local planning regulations (see, for example, Barker, 2003). Cross sectional variance in the elasticity of housing supply is largely determined by variation in planning regulations. If in one location the supply of houses is fixed whilst it is highly elastic in another, then the measured capitalisation of school quality will vary even though demand is invariant.

Variation in land use planning (or zoning) policies implies that we may observe substantial differences in the supply characteristics of school quality between cities. Furthermore, there may be differences in the supply of school quality within cities. This may arise because of differing elasticities of supply of housing according to location. Cheshire and Sheppard (1995) identified substantial differences in the degree of planning restriction on housing supply between cities that corresponded with differences in the capitalised price of secondary schools. The market from which the data for the present study are drawn, Reading in southern England, is subject to restrictive policies of urban containment, so there will be a relatively inelastic supply of housing in the whole area but localised housing supply will vary from location to location within it, as particular parcels of land are released.

Local variation in housing supply elasticity, and its impact on capitalisation has been the focus of recent research in US housing markets. Hilber and Mayer (2002) and Brasington (2002) have drawn attention to the fact that the extent of capitalisation may be reduced in areas where housing supply would be expected to be more elastic. Comparing across cities in Massachusetts, Hilber and Mayer find empirical support for the observation. Comparing central with peripheral residential properties in urban areas of Ohio, Brasington finds that the capitalised value of a given level of quality is reduced for houses at the edge of the urban area.

It is possible that observed reductions in capitalisation might exist for other reasons, related to the availability of substitute sources of education, variation in the physical characteristics of the housing stock, making it more or less suitable for accommodating children or the degree of uncertainty attached to current measures of school quality discussed below. Before proceeding to consider these factors, we note a final explanation related to the regulation of housing supply. An apparent discount in the implicit price of school quality could be due to a land use planning system that concentrates new construction in localities with significant local disamenities (and hence reduced opposition to new development), where the disamenities are difficult to measure and so control for. In this case apparent discounting of school quality might reflect the impact of such omitted variables.

B. State School Quality and the Availability of Substitutes

Even if the supply of housing were completely inelastic, house values would be little affected by school quality if substitute sources of quality education were readily available. In such cases, the only impact of state-supported school quality on house values would be an accessibility premium related to proximity to the school. This distance related premium might be expected to be higher for primary schools since children younger than 10 or 11 are more likely to be taken to school by a parent, increasing the cost of distance.

In Reading, there are four possible substitutes for the dedicated state school (and these may vary between the primary and secondary levels). These are (1) a private school, (2) a church (parochial) school, (3) admission to a state-supported ‘Grammar School’ and (4) obtaining a transfer to a state-supported school other than the one designated as serving the address.

Reading is a relatively high-income community, well endowed with private schools, particularly at secondary level. This suggests there will be an upper limit on the capitalised price of school quality. Access to private schooling is controlled largely by income not location, so if a given degree of school quality can always be purchased in the private market for educational services, this price will determine the upper limit of the capitalised value of state school quality, but the cost of private schools implies that this upper limit will be relatively high.

At the primary school level (i.e. for children below the age of 11) there are a variety of state-funded church schools, admission to which is more loosely related to home address. While in some neighbourhoods this might be a factor, there are indirect costs associated with church schools. For example, Gibbons and Machin (2003) point out that such education entails a cost associated with conforming to religious requirements. This suggests that church schools may be similar to the availability of private education in its overall impact: it places an upper limit on the estimated value of educational quality, but this limit will tend to be relatively high.

The impact of the continued existence of Grammar Schools in Reading (state-supported secondary schools with entry highly selective according to tested academic ability) on the capitalisation of school quality can probably be safely ignored. Entry is so selective and possible for such a small proportion of the cohort that the risk associated with assuming one's child will gain admission must be very great.

A considerably more plausible influence on the extent of capitalisation of school quality is the possibility that a household requests and is granted permission to send their children to a state-supported school other than the one to which the house would usually be allocated. At the limit, if parents could freely choose any school, then, except for the distance costs, the supply of school quality for every home would be perfectly elastic. The frequency with which appeals against school assignment are successful determines the overall 'porosity' of school catchment zones.

In England (as in many other countries) each house is assigned to a default primary and secondary school. Parents may in principle nominate any school for their child but presumably there is considerable inertia: most parents simply accept the local school. In requesting a different school to the local one, parents are presumably influenced by their perception of the probability of such a nomination being successful. If they choose a school other than their default school and the local education authority (LEA) does not accept this choice then parents may appeal. Again it is likely that in deciding whether to appeal parents take some account of the probability of success since the appeal process takes some time and effort.

In trying to compare differences in the underlying 'porosity' – the probability that a child living at a particular address will actually attend the local default school in the catchment area of which the house is located – we are hampered by only being able to observe some of the relevant variables. There are no data on the proportion of parents choosing a non-local school or on the proportion of such choices that are rejected by the LEA. Since 1997, however, there are systematic data on the appeals process. Figures are published for all LEAs in England on the total number of admissions to primary and secondary schools, on the number of appeals against the allocations made by parents and the outcome of these appeals. Data are available for all LEAs but we have just selected a number for comparison in Table 1. The choice of England as a whole, London and the combined LEAs which serve the Reading housing market area is self-explanatory. Oxfordshire is the LEA adjoining Reading to the north; the housing market areas of Nottingham and Darlington have been studied by the present authors elsewhere (see Cheshire, Marlee and Sheppard, 1999) although the focus in that study was on the impact of land supply on house prices. Manchester is a representative large city in the north of England and Cheshire is typical of a number of northern LEAs which have a high success rate for appeals – over 60 % at the secondary school level. Together these LEAs represent a wide range of the observed pattern.

Table 1: Success rate of Appeals against School Allocation
Relative to Admissions (1) and per Appeal (2)

Authority	Primary Schools								Secondary Schools							
	1997-98		1998-99		1999-00		Mean		1997-98		1998-99		1999-00		Mean	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
England	1.7	31.0	1.6	29.0	1.3	25.4	1.5	28.5	1.8	23.3	2.0	23.5	2.3	23.5	2.0	23.4
Reading Area[3]	1.6	31.4	3.7	31.2	1.7	17.3	2.3	26.6	0.4	7.5	0.6	15.6	0.5	9.6	0.5	10.9
Inner London	1.5	16.0	1.2	15.1	0.6	8.9	1.1	13.3	1.8	15.0	1.7	9.3	1.6	8.3	2.1	10.9
Greater London	2.7	23.6	2.1	20.3	1.3	15.7	2.0	19.9	2.2	13.9	2.2	11.9	2.7	13.3	2.4	13.0
Oxfordshire	1.3	43.0	1.6	47.6	1.2	42.4	1.4	44.3	1.5	38.4	2.1	45.4	1.5	33.3	1.7	39.0
Darlington	7.1	44.9	8.8	40.7	6.0	41.5	7.3	42.4	4.1	34.3	4.7	37.1	2.5	31.6	3.8	34.3
Nottingham	0.4	30.3	0.8	28.4	1.4	35.2	0.9	31.3	0.5	21.7	0.8	17.6	1.0	23.7	0.8	21.0
Manchester	2.2	28.0	2.8	38.7	1.7	25.7	2.2	30.8	1.2	14.7	2.1	24.1	2.1	18.2	1.8	19.0
Cheshire	0.1	27.5	0.7	69.2	0.7	51.3	0.5	49.3	0.5	62.7	2.0	59.3	3.9	65.0	2.1	62.3

[1]Successful Appeals as % of Total Admissions [2]Successful Appeals as % of Total Appeals [3]Weighted mean for three Local Education Authorities: weights determined by distribution of sampled houses

Patterns are reasonably consistent between LEAs. Darlington has a high rate of successful appeals, and Cheshire has a low rate relative to admissions but a high proportion of the appeals that there are, are successful (perhaps indicating a very flexible policy with a high rate of unobserved nominations of non-local schools as well). Inner London has a low rate of both successful appeals relative to admissions and relative to appeals. This may reasonably be interpreted as indicating an inflexible regime in which the school a child attends is largely determined by home address.

The data for Reading suggest a regime that is rather less restrictive than that of Inner London at the primary level but even more restrictive at the secondary level. Looking at the mean rates for the three years only 0.5 % of children successfully appealed against their secondary school allocation in the Reading area (one quarter the success rate of Inner London or England as a whole) and 10 % of appeals were successful – the same as Inner London but half the proportion of England and one sixth that of Cheshire.

C. Risk of Variation in School Quality

The relevant measure of school quality should be *expected* school quality. The quality of a school can change over time so current school quality as an indicator of expected school quality is subject to a degree of risk. There are various possible sources of future change but one is boundary redefinition. Since LEAs are responsible for defining school catchment areas they can revise them on a regular basis in order to fill available school places and eliminate spare capacity. Officials from the LEAs responsible for the Reading area have confirmed that this is standard practice there. This creates uncertainty for the buyer concerning which school will serve the house in the future, especially in those parts of the urban area where the number of children of school age is less stable. Since the limited land release for development that does occur in Reading takes place mostly at the urban periphery, for properties located near the edge of the built up area there is an added source of uncertainty. Not only is it less certain to which school their home will be assigned by the LEA but the nature of the population who will be served by the school is also more likely to change. The combined impact of these considerations is to impose greater risk of variation in school quality in some areas (primarily the periphery and, particularly in areas of new construction) of the market than in others.

The evidence reviewed above supports the conclusion that in the area from which our sample is drawn, Reading, most children go to the school determined by the location of their home and by the boundaries of the catchment areas in force in the year they first go to either primary (at 5 years) or secondary school (at 11). This probability is significantly higher at the secondary school level and is very high by the standards of England as a whole.

Let us summarise our observations concerning the elasticity of supply of school quality (or at least supply as measured by those variables we are using to capture it). If parents are concerned to increase the probability of their child(ren) attaining a particular level of qualification then their choice at the primary level will be between: a secular state primary, a church school or a private school. If they choose a state school then they can move to the catchment area of the school of their choice, trading off price against quality; or they can try to obtain entry to a more distant –

probably a church – school and pay a price in the journey to school and church. *De facto* there is more flexibility (that is an ability to exercise choice of school) at primary than at secondary school level. These considerations suggest the supply of school quality at primary level may be more elastic than it is at the secondary school level.

At the secondary level parents can make similar choices except that in Reading there is a strong constraint against choosing any secondary school other than the one in the catchment area of which they live. Boundaries of catchment areas are revised annually, adding some uncertainty to the correspondence between school and residential address and this uncertainty is likely to be systematically higher in lower density areas on the periphery and in those areas where new construction is concentrated, as LEAs attempt to manipulate intakes to utilise school capacity.

3. Data and Setting

Reading, England, the urban area from which our data are drawn is located on the Thames about 35 miles west of central London. Reading is subject to considerable pressure for growth and residential development, and has adopted some of the most restrictive planning policies in England and Wales. With frequent high-speed rail links to London, proximity to Heathrow airport and other locational advantages the area has attracted a number of high technology firms[4] and more generally follows the development patterns typical of prosperous, middle-size cities of the southeast of England. Despite its proximity to London, Reading is a major employment centre with more than 85% of its employed residents working locally and a strong central business district employment concentration. It is a reasonable city, therefore, to which to apply the familiar monocentric model of urban land use as developed by Alonso (1964) or Mills (1967).

In 1991 the city had a population of approximately 337,000 persons in its wider urban region comprising 129,000 households. For the 1999/2000 period the present data relate to we estimate that there were 131,370 households in the urban area as defined from 1991 Census wards. Our initial sample of properties comprised over 870 separate structures. This provided a sample of approximately 20% of the residential properties offered for sale by major estate agents during the sampled 17 months. Complete data including location, structure characteristics, sales date and price, and school assignments were available for 490 observations and these are used in the analysis below.

[4] Microsoft, Oracle, Hewlett-Packard and others

Supplemental information on land use was assembled from Ordnance Survey resources and aerial photographs. Data on both secondary and primary school catchment areas were obtained from the local education authorities. Data on the quality of state (in US English – public) schools were obtained from the Department of Education website[5]. The measure used for primary schools was the performance of its pupils on the Key Stage 2 tests[6] for the most recent year prior to the date of sale. For secondary schools the measure of school quality was the proportion of pupils obtaining 5 or more passes at grade C or better in GCSE,[7] again for the most recent year. Data on the availability, performance and price of local private schools were obtained from the ISIS website. The Department of Local Government, Transport and the Regions' (DETR) index of employment deprivation was used as the measure of the socio-economic characteristics of the neighbourhood. Table 2 provides some descriptive statistics for the sample and a description of each variable used in the analysis.

[5] http://www.dfes.gov.uk/statistics/DB/SBU/b0333/index.html

[6] Tests administered nationwide and designed to assess achievement in mastering that portion of the national curriculum, known as 'Key Stage 2', deemed appropriate for ages 7 to 11.

[7] A nationwide exam taken at minimum school leaving age, 16.

Table 2: Variable Descriptions and Descriptive Statistics

Variable	Mean	σ	Min	Max	Description
Price	126.9378	48.6852	45	385	Price in thousands of pounds
Detached	0.0984	0.2981	0	1	1 if property is a detached house
Semi-detached	0.1687	0.3748	0	1	1 if property is a semi-detached house
Terrace	0.3896	0.4881	0	1	1 if property is a terrace house
Townhouse	0.1024	0.3035	0	1	1 if property is a townhouse
Parking	0.3153	0.4651	0	1	1 if property has off-street parking
Thames	0.0080	0.0894	0	1	1 if centre of plot is within 150 m of Thames
Rail	0.1104	0.3138	0	1	1 if centre of plot is within 200 m of rail line
Cul-de-sac	0.2209	0.4153	0	1	1 if property is located on a cul-de-sac
Minor Road	0.6386	0.4809	0	1	1 if property is located on minor through street
B-Road	0.0161	0.1258	0	1	1 if located on "B" class roadway
A-Road	0.0482	0.2144	0	1	1 if located on "A" class roadway
Time Trend	0.9351	0.3020	0	1.4740	Years since 6/1999 (time trend)
Bedrooms	2.5815	0.8436	0	6	Number of bedrooms
Baths	1.3448	0.6576	0	5	Number of bathrooms
Nosquare	0.6103	0.1814	0.1854	1.0408	Ratio of plot size to perimeter
SqFt	676.115	242.132	189.861	1749.014	Square feet of internal living space in house
Ethnic	4.6290	2.3438	0.0470	8.8660	% of Census ward population of Afro-Caribbean descent 1991
Industry	10.6827	11.7065	0	50	% of land within 1 km square in industrial use
EmployDepriv	7.0933	2.2435	2.4418	10.2846	DETR index of employment deprivation
Plotsize	222.6534	214.7078	22.1088	2054.5471	Plot size in square metres
Distance	2289.1982	1462.9522	54.6539	8331.3380	Distance from town centre in metres
θ	-0.4863	2.0548	-3.1391	3.1391	Direction in radians from town centre (East=0)
PrimarySchool	1.8654	0.4713	1.14	2.84	Sum of share of pupils in assigned school passing Key Stage 2 exams in English, Math, and Science
SecondarySchool	0.3469	0.1390	0.1	0.75	Share of pupils in assigned school receiving a grade of C or better in 5 or more GCSE exams
PrimarySchool	1.8457	0.4650	1.14	2.86	Sum of share of pupils in nearest school passing Key Stage 2 exams in English, Math, and Science (Models II and IV)
SecondarySchool	0.3633	0.1356	0.05	0.72	Share of pupils in nearest school receiving a grade of C or better in 5 or more GCSE subject exams (Models II and IV)
PrimarySchool S.D.	0.3456	0.1373	0.0908	0.6770	Standard Deviation of PrimarySchool measured over period 1996-2001
SecondarySchool S.D	0.0508	0.0258	0.0137	0.0821	Standard Deviation of SecondarySchool measured over period 1996-2001
Periphery	0.0944	0.2926	0	1	1 if Property located in peripheral ward with new construction

4. The Hedonic Model

Our basic model follows a procedure similar to that set out in Cheshire and Sheppard (1995, 1998). We precisely locate each house in the sample and measure the size of the plot of land associated with it. We then estimate a modified linear Box-Cox hedonic price function given in equation (1). Note that the value function for urban residential land, specified in equation (2), is estimated directly as part of the hedonic price function. The land rent is 'monotonic' only in the sense that it is radially symmetric so that land value must increase or decrease at the same rate in any given direction away from the urban centre.

$$\frac{P^{\psi}-1}{\psi} = K + \sum_{i \in D} \beta_i \cdot q_i + \sum_{j \in C} \beta_j \cdot \left(\frac{q_j^{\lambda_1} - 1}{\lambda_1} \right) + \sum_{k \in E} \beta_k \cdot \left(\frac{q_k^{\lambda_2} - 1}{\lambda_2} \right) + r(x,\theta)\frac{L^{\xi}-1}{\xi} \quad (1)$$

where:

P	=	sales price of structure
q_i, q_j	=	structure and location-specific characteristics
$K, \beta_i, \lambda_i, \psi, \xi$	=	parameters to be estimated
L	=	quantity of land included with structure
D	=	set of indices of characteristics which are dichotomous
C	=	set of indices of characteristics which are continuously variable
E	=	set of indices of characteristics measuring educational quality
$r(x, \theta)$	=	land rent function given by:

$$r(x,\theta) = \beta_1 \cdot e^{x \cdot (\beta_2 + \beta_3 \cdot \mathbf{sin}(n \cdot \theta - \beta_4))} \quad (2)$$

where:

x	=	Distance from the city centre
θ	=	Angle of deflection from the city centre
n	=	Number of 'ridges' in land value, representing radial asymmetries
β_i	=	Estimated parameters of land value function

The classic monocentric urban model assumes symmetrical transport systems implying that the land value surface will be symmetrical. In actual cities, however, the costs of access to the centre will normally vary depending on the direction of travel determined by the orientation of the main transport infrastructure. The orientation of this infrastructure – typically the main road access to the city centre – should be expected to give rise to asymmetries in the value surface taking the form of 'ridges' tracking the main road access. Searching over a small grid (1-4) it was determined that a rent function with n=3 ridges provided the best fit to the data. The estimated land value depends on the location and also the size of the plot and type of structure built upon it. For a structure matching the sample mean in all attributes (except location) the spatial structure of the estimated land value function is illustrated below in Figs. 1 and 2.

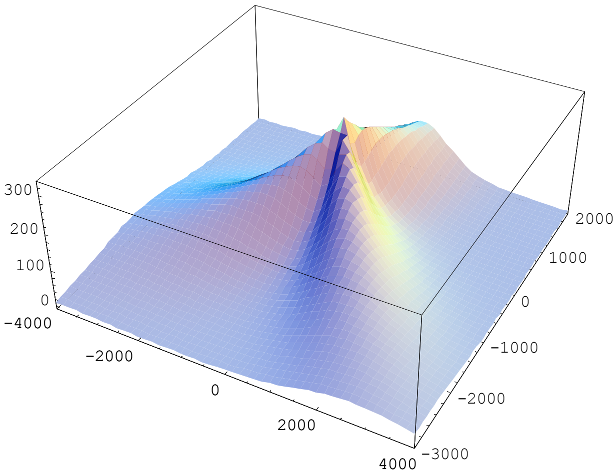


Fig. 1 – Plot of land value per acre

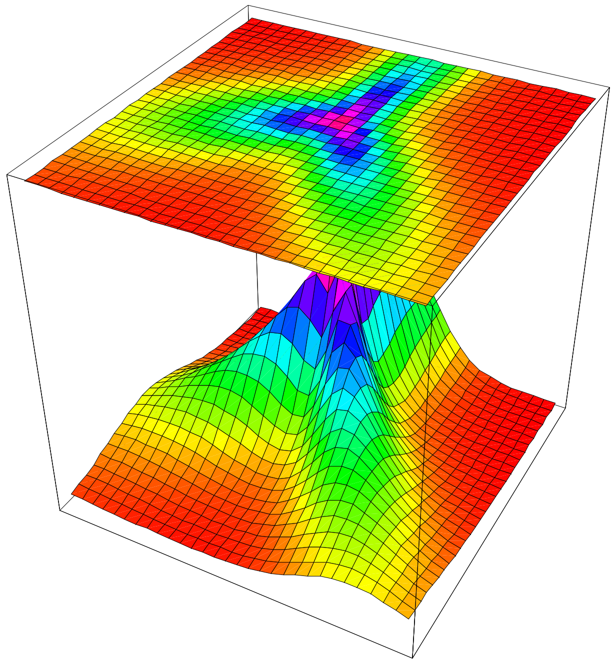


Fig. 2 – Land value with contours

The surface is viewed from the southeast looking towards the northwest. The three ridges closely track the local transport system. They are aligned with the main road access routes to the city centre: the A329M linking the main London Bristol motorway – the M4 – to the centre from its eastern junction; the access route from the M4 at its junction to the south of the city along the A33; and the main route, again linking to the M4, to the west of the city along the A4.

The measure of the value of land shown in Figs. 1 and 2 is essentially the price of 'land as pure space with accessibility'. Actual market prices of vacant land include the capitalised value of all the local amenities, neighbourhood characteristics and local public goods to which occupation of the land gives access. As was shown in Cheshire and Sheppard (1998) these amenity values typically exceed the value of land as pure space with accessibility[8].

5. Interpreting the results

[8] In the data studied in Cheshire and Sheppard (1998) the amenity values were greater by a factor of up to eight

We follow a similar estimation strategy to that set out in Cheshire and Sheppard, 1995. The results for six models are presented in Table 3[9]. Model I presents estimates of a basic model including measures of the quality of the primary and secondary schools to which the address is assigned by the local education authority. Model II presents an estimate of the same model, but using the quality measures of the primary and secondary school that are nearest (straight-line distance) to the house. Model III presents a model using the measures of school quality at the assigned schools, but drops the DETR Employment Deprivation index[10], and Model IV repeats this structure using the school quality measures from the nearest schools. In all these cases the value of the quality measures for educational quality reported most recently prior to the sale (and so available to the purchaser) is applied.

The last two models test for the impact of past variation in the measure of school quality and the suitability for children of the dwelling's physical characteristics on estimated quality capitalisation. They also include an index for the house being located in an area of the urban periphery that has experienced considerable new construction. In Model V this index is included in a way that allows estimation of any discounting of the value of school quality and its variability for houses in these areas; in Model VI a simple dummy variable is incorporated if the house is located in a (peripheral) area within which new construction has been concentrated. The rationale and specification of Models V and VI are discussed in more detail below.

[9] One aspect of this strategy is to test carefully for problems of collinearity, particularly in the structural characteristics of houses, and drop those where this is a problem and especially where they can be subsumed in other characteristics. In these models for example Bathrooms subsume separate WCs and Off-street parking subsumes garages.

[10] Given the lack of neighbourhood income estimates in Britain several of the available deprivation indices were tried. The multiple index of deprivation worked best in a statistical sense but, because one small element of that is the performance of the local primary school on Key Stage 2, the results obtained using the employment deprivation index are the focus of our analysis.

Table 3: Estimated parameters for Models I to VI, with t-statistics for each estimate.

Parameter	**Model I** Basic Model	**Model II** Nearest not assigned Schools	**Model III** No Local Deprivation Index	**Model IV** Nearest Schools+ No Deprivation index	**Model V** Discounting for Risk, New construction & Child capacity	**Model VI** As Model V but shift dummy for New construction
β_0	3.124553	3.236343	3.336312	3.29032	2.98713	2.988932
t	*29.601*	*11.183*	*31.084*	*16.088*	*134.114*	*130.096*
$\beta_{Detached}$	0.185303	0.201205	0.238915	0.224075	0.188676	0.187413
t	*8.469*	*4.751*	*12.608*	*6.321*	*8.496*	*9.559*
$\beta_{Semi\text{-}detached}$	0.119002	0.134669	0.150193	0.14736	0.114038	0.113261
t	*6.800*	*4.798*	*9.395*	*6.204*	*5.124*	*5.343*
$\beta_{Terrace}$	0.051215	0.054739	0.066083	0.058462	0.055143	0.054152
t	*4.195*	*3.517*	*5.544*	*4.425*	*4.241*	*4.058*
$\beta_{Townhouse}$	0.07224	0.080601	0.084975	0.081427	0.076023	0.075155
t	*4.868*	*4.201*	*5.853*	*4.648*	*3.647*	*3.630*
$\beta_{Parking}$	0.011386	0.010764	0.01165	0.007322	0.013094	0.013630
t	*1.742*	*1.607*	*1.762*	*1.062*	*0.886*	*1.555*
β_{Thames}	0.074639	0.091209	0.09254	0.107257	0.075568	0.075267
t	*2.339*	*2.487*	*2.991*	*2.825*	*1.641*	*2.804*
β_{Rail}	-0.00837	-0.00985	-0.0076	-0.00957	-0.010269	-0.010543
t	*-0.949*	*-1.052*	*-0.855*	*-1.002*	*-0.546*	*-0.577*
$\beta_{Cul\text{-}de\text{-}sac}$	0.030018	0.03431	0.05332	0.050991	0.037955	0.035173
t	*2.265*	*2.234*	*4.197*	*3.389*	*2.074*	*2.204*
$\beta_{Minor\ Rd.}$	0.005123	0.006463	0.019676	0.018172	0.015350	0.012631
t	*0.452*	*0.565*	*1.749*	*1.559*	*0.942*	*0.922*
$\beta_{B\text{-}Road}$	0.099615	0.109639	0.139194	0.133493	0.117888	0.113314
t	*3.814*	*3.203*	*5.448*	*4.254*	*4.586*	*3.963*
$\beta_{A\text{-}Road}$	-0.0013	-0.00385	0.024584	0.011935	-0.000136	-0.004564
t	*-0.071*	*-0.227*	*1.381*	*0.679*	*-0.006*	*-0.200*
$\beta_{TimeTrend}$	0.029917	0.034401	0.037374	0.041336	0.030664	0.030699
t	*3.185*	*2.931*	*4.153*	*3.862*	*1.596*	*1.754*
$\beta_{Bedrooms}$	0.02032	0.024127	0.027871	0.025885	0.011317	0.011279
t	*3.031*	*2.955*	*3.939*	*3.619*	*1.097*	*1.410*
$\beta_{Bathrooms}$	0.051009	0.055213	0.061564	0.062694	0.071603	0.070477
t	*6.320*	*4.717*	*8.261*	*6.458*	*6.009*	*7.549*
$\beta_{Notsquare}$	0.04914	0.052667	0.063436	0.053442	0.044112	0.042959
t	*2.848*	*2.469*	*3.579*	*2.745*	*2.081*	*2.110*
β_{SqFt}	0.007772	0.005708	0.005827	0.007122	0.020549	0.020357
t	*18.951*	*6.457*	*21.543*	*10.140*	*12.534*	*11.171*
B_{ethnic}					*-0.005855*	*-0.004724*
t					*-1.036*	*-0.799*
$\beta_{IndustrialLand}$	-0.00113	-0.0014	-0.00137	-0.00214	-0.000599	-0.000995
t	*-1.663*	*-2.071*	*-2.083*	*-2.780*	*-0.427*	*-0.691*
$\beta_{EmployDepriv}$	-0.02416	-0.02372			-0.018370	-0.018487
t	*-5.899*	*-6.048*			*-4.419*	*-4.250*
$\beta_{PrimarySchool}$	**0.000836**	**0.000971**	**0.005957**	**0.002127**	**0.001524**	**0.001277**
t	2.461	1.384	1.854	1.656	4.163	4.214
$\beta_{PrimarySchool\ S.D.}$					**-0.095804**	**-0.096449**
t					*-4.142*	*-4.333*
$\beta_{SecondarySchool}$	**0.588393**	**0.335556**	**0.474515**	**0.513499**	**0.041381**	**0.040883**
t	*6.215*	*4.766*	*4.212*	*3.557*	*1.787*	*1.864*
$\beta_{SecondarySchool\ S.D.}$					**-0.088845**	***-0.089455***
t					*-3.868*	*-4.027*
$\beta1$	0.00766	0.009199	0.001622	0.001981	0.006635	0.006713
t	*1.352*	*4.447*	*5.059*	*1.577*	*4.179*	*4.266*
$\beta2$	-0.00095	-0.00097	-0.00141	-0.00108	-0.000827	-0.000798

Parameter	Model I Basic Model	Model II Nearest not assigned Schools	Model III No Local Deprivation Index	Model IV Nearest Schools+ No Deprivation index	Model V Discounting for Risk, New construction & Child capacity	Model VI As Model V but shift dummy for New construction
t	*-3.148*	*-3.502*	*-2.349*	*-2.610*	*-3.296*	*-2.866*
β3	0.000516	0.000485	0.001067	0.000606	0.000428	0.000394
t	*1.953*	*2.190*	*1.724*	*1.647*	*1.979*	*1.651*
β4	-3.79069	-3.87525	-3.9581	-4.07902	-3.812222	-3.811957
t	*-23.445*	*-21.723*	*-21.876*	*-17.254*	*-99.727*	*-147.837*
λ_1	0.500048	0.551618	0.576605	0.531902	0.360893	0.361161
t	*24.429*	*9.681*	*48.943*	*13.406*	*13.135*	*15.566*
λ_2	6.445736	6.508272	4.710182	6.026819	6.961245	6.960813
t	*11.943*	*8.204*	*7.628*	*8.719*	*314.276*	*299.666*
ξ	0.417822	0.425036	0.73667	0.737899	0.445310	0.444501
t	*2.257*	*4.063*	*9.434*	*5.473*	*19.381*	*19.429*
Ψ	-0.14056	-0.1213	-0.09503	-0.10093	-0.128824	-0.129521
t	*-7.913*	*-2.794*	*-8.552*	*-3.568*	*-21.153*	*-22.378*
$\beta_{Periphery}$					-0.398027	-0.011234
t					*-7.607*	*-0.577*
σ	0.075256	0.082311	0.095002	0.092192	0.078471	0.078423
	10.913	*4.735*	*18.492*	*6.946*	*22.067*	*23.818*
Log Likelihood	-2103.11	-2101.9	-2110.45	-2109.55	-2087.01	-2088.27
N	490	490	490	490	488	488

β1,…, β4 are the parameters of the rent function (see equation 2)
Ψ, ξ, λ_1, λ_2 are the Box-Cox transformation parameters for respectively house price (the dependent variable), land, continuous variables (other than school quality) and school quality

A. Value of Primary and Secondary Schools

Using the basic models in which the results are easier to interpret, we start by addressing the question: which types of schools are of greater value to purchasers of houses? There are at least two different approaches to this question, and it turns out (at least in the Reading housing market in 2000) that each approach gives a somewhat different answer.

The first approach is simply to compare the estimated hedonic prices of each measure of school quality. Examination of the parameter estimates in Table 3 shows that the estimated parameter for the quality of secondary schools is considerably larger than for primary schools (as well as having a larger t value associated with it). A better comparison is afforded if we standardise the ranges of the quality measures. Fig. 3 presents plots of the hedonic price (in thousands of pounds[11]) for both the measure of secondary and primary school quality, standardised so that the movement from 0 to 1 represents the total possible range of outcomes in the quality measure. At comparable levels, the secondary school quality is ‘more valuable’. It is notable how non-linear the price paid for school quality appears to be; better quality really only commands a substantial price in the top one third of the school quality distribution.

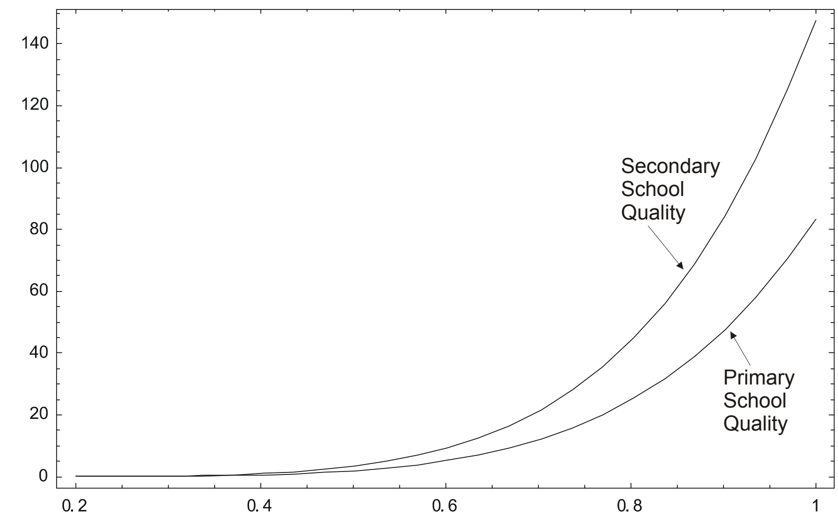


Figure 3: Comparison of price of quality

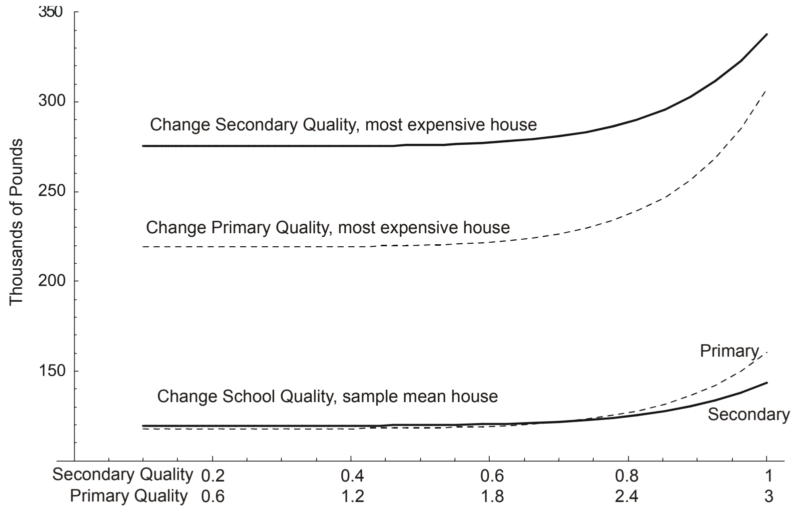
An alternative approach is to ask which factor contributes the most to the value of houses within our sample. This question is different because of differences in the range of measured school qualities; as indicated in Table 2, the standard deviation of primary school quality is more than three time that of secondary schools. This is reflected in the estimated change in value of an average house as we move from the lowest to highest measured quality in the sample.

Fig. 4 provides one way of examining this issue. The figure shows the predicted value of the average (bottom curve) and the most expensive (top curve) house in the sample as secondary (solid line) or primary (dashed line) school quality varies from the lowest observed level to the

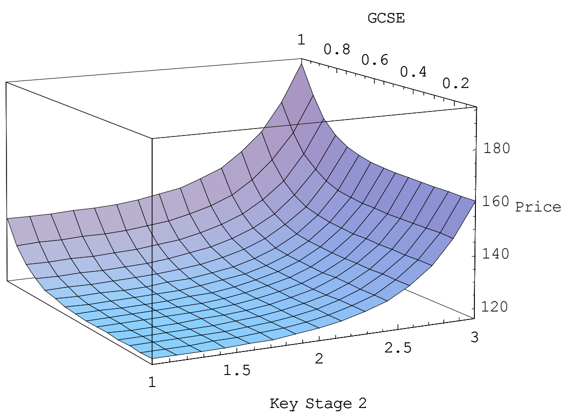
[11] Evaluated for a house whose value and other characteristics are equal to sample mean values.

maximum possible (the vertical axis is measured in thousands of pounds, while the horizontal axis is measured as indicated for secondary and primary school quality).

Figure 4: Impact of School Quality on House Prices



Figs. 5 and 6 provide a visual representation of the joint impact of school quality of both types on the price of an 'average' house, along with the distribution of observations in the sample within different ranges of the school quality spectrum. Fig. 5 provides a surface that illustrates the impact on house values of changes in both primary (Key Stage 2) and secondary (GCSE) school quality. Fig. 6 superimposes this surface over a 'histogram' that shows the share of sample observations within each range of qualities.



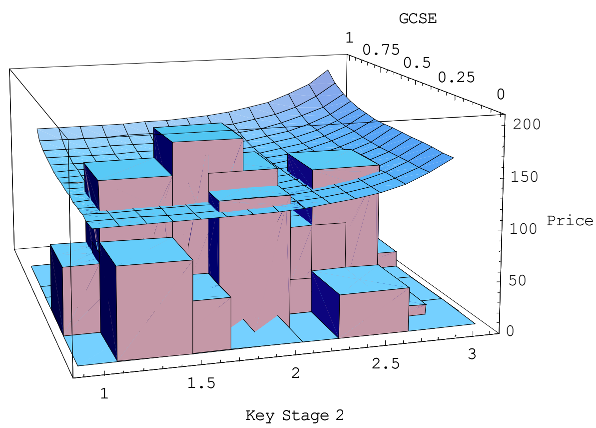


Fig. 5 – Impact of quality on house price

Fig. 6 – Impact and distribution of quality

It is apparent that the distribution of state-sector secondary schools is concentrated in the lower to middle quality range, while the distribution of state supported primary schools covers a broader range of quality. Whether this is the cause of, or caused by the availability if non-state supported secondary schools that through competitive entry specialize in the middle to upper quality range is interesting but not central to our analysis. It is the state-supported sector that makes location of residence an important factor in determining the school available to a household's children, and it is the quality in this sector that will be capitalised into house values.

In summary, while the hedonic price of secondary school quality is higher than the price of primary school quality, moving from the worst to the best possible secondary school would increase the value of the average house by £23,763 (or 18.7 % of the value of a mean house). Moving from the worst to the best possible primary school would increase the value of the average house by £42,541 (33.5 % of the mean house value). In passing it may be noted that the value added to the price of a mean characteristics house moving it from the catchment area of the worst to the best secondary school estimated from a sample drawn for Reading in 1984 was 13.9 % (see Cheshire and Sheppard (1995)) and for 1993 was 14.1 % (Cheshire, Monastiriotis and Sheppard (2000)). Neither hedonic model used for these earlier periods included primary school quality since Key Stage 2 test results were not available then. Leech and Campos (2003) examine the impact on house prices in Coventry, and estimate a 20% premium associated with location in a desirable secondary school area compared with a less desirable one. A recent study in Christchurch New Zealand (McClay and Harrison, 2004) found a premium relative to the sample mean price of 48% for the best girls' school and 28% for the best boys' school with the premium for the best girls' school about equal to the opportunity cost of private school fees.

B. Models with Measurement Error: Nearest vs. Assigned Schools

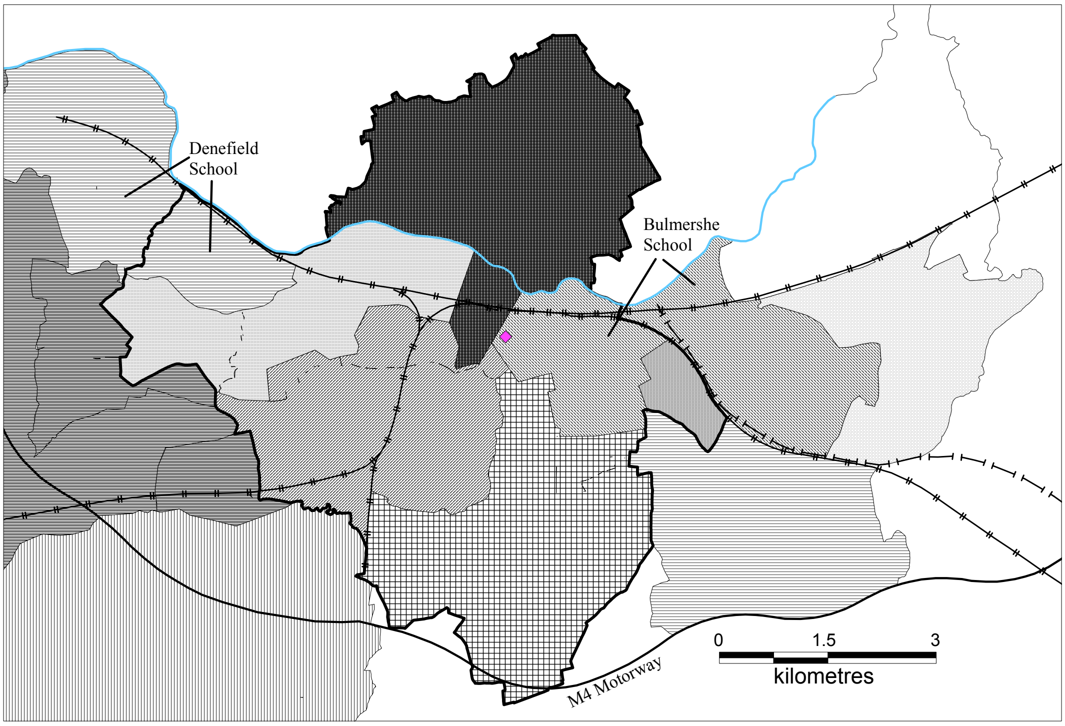
Assignment of houses to a default primary and secondary school is up to the LEA. This information is not available from any central source, and for some education authorities can be difficult to obtain. Partly for this reason some studies of the effects of school quality often do not actually use the quality level of the assigned school, but rather the quality level of the school (primary or secondary) that is located nearest to the house. While this is feasible, there is a question as to whether it provides a good approximation of the school quality that would actually be available to the residents of a particular house. For our sample we determined assigned catchment area for each observation from either published maps[12] or from an online service provided by the LEA that allowed entry of addresses and responded with assigned schools.[13] Fig. 7, shows the secondary school catchment areas for the Reading housing market in 1999/2000 determined either directly from the maps or from the pattern of responses provided by the online service.

[12] For the West Berkshire LEA.
[13] For Reading and Wokingham LEAs.

The map shows that many catchment areas are irregular and elongated, implying that the nearest school is often not a reliable proxy for the school to which an address is assigned. There are examples of non-contiguous catchment areas in the sparsely populated western periphery of the area. Finally, there are two examples of school catchment areas that span local authority boundaries, an arrangement that makes cooperative use of local buildings and fixed capital but that poses problems for econometric specifications assuming that such situations do not arise, and suggests the potential importance of precise determination of assigned school for each house.

Fig. 7

Secondary School Catchment Areas



The irregularity of areas and assignment of houses to schools other than the nearest school is also clear in the primary school catchment areas. A sample of three relatively typical catchment areas is shown in Fig. 8, along with the locations of sample properties in each area and surrounding areas and the location of the school buildings for each area. Because school buildings are not necessarily located near the centre of the catchment area, and the areas themselves are irregular in shape, assigning houses to the nearest school will result in significant mis-classification of properties.

Appendix Table 1 presents the correlations (across properties in our sample) between quality variables for assigned and for nearest schools. It is immediately apparent that the correlation between the quality measures for assigned schools and closest schools is low. In the case of secondary schools, which have larger catchment areas, the correlation is only 0.435.

Selected Primary School Catchment Areas

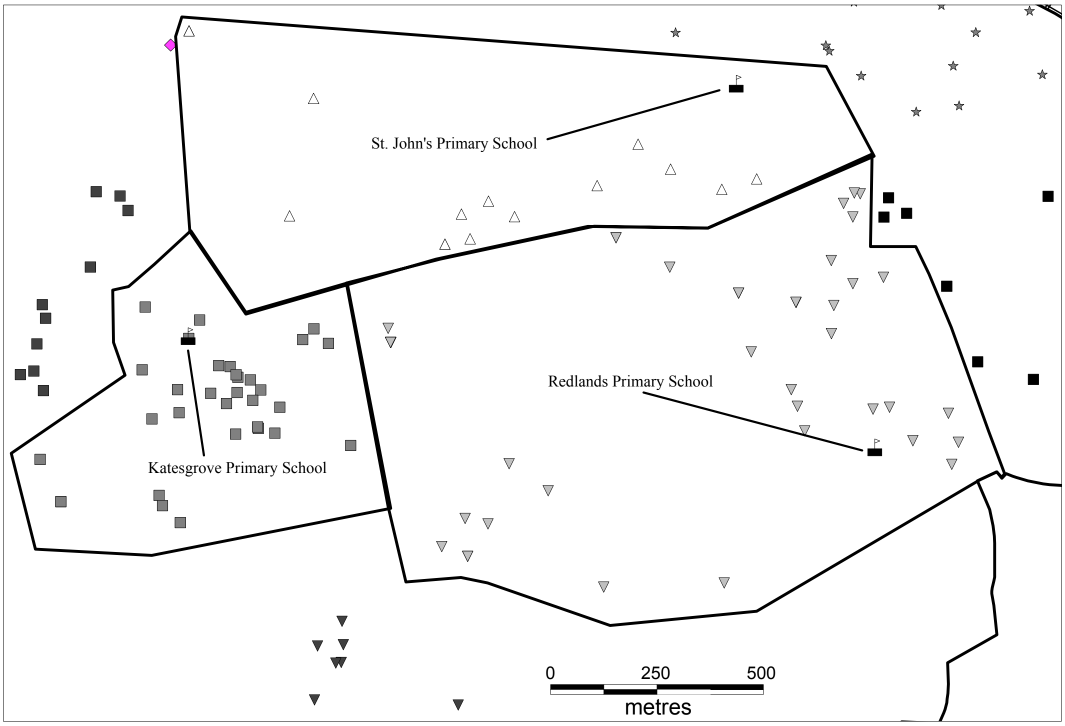


Fig. 8

Comparing the estimated parameters for models I and II (shown in Table 3) we see that using quality measures for schools actually assigned to addresses provides a better fit for the data than using the values for the closest school. The t values for the relevant parameters fall and that for primary schools ceases to be significantly different from zero. These results suggest that caution is certainly appropriate when interpreting estimates based on measurement of school quality using the nearest school rather than the assigned school.

C. Quality of Schools and Neighbourhoods: Estimation with Omitted Variables

A further concern in the evaluation of school quality arises because the school catchment area, particularly for primary schools, may serve as an approximation for more localised amenities and neighbourhood effects. Therefore omitted variables, particularly those related to neighbourhood quality, may bias the estimates of the value of educational quality. To evaluate the impact of this we examine the effect on model estimation when the DETR employment deprivation index variable is dropped. This variable provides a measure of concentration in the neighbourhood (census ward) of people having little success in the local labour market. It therefore helps to capture the socio-economic character of the neighbourhood.

Dropping the measure of the socio-economic character of the neighbourhood substantially increases the estimated value of the primary school parameter – it increases sevenfold in absolute terms – but because it impairs the overall performance of the model its t value is still lower than in Model I. The estimate for the secondary school parameter falls in absolute terms if the deprivation index is dropped, although it remains statistically significant. This provides justification for concern that there is likely to be an upward bias in the estimated impact of primary school quality on house prices if other important local neighbourhood effects are not independently controlled for.

D. Discounting School Quality: The Role of Uncertainty, House Characteristics and New Construction

Models V and VI explore some rather more subtle issues. It has been argued in the literature in the US that differences in land availability and new construction between communities will generate differences in the elasticity of supply of educational quality. Hilber and Mayer (2002) focus on inter community differences whereas Brasington (2002) investigates the possible impact of land availability and new construction in the centre compared to the suburbs of the same city. Where new construction is possible some of the increased demand associated with better schools may be accommodated by increases in the local supply of housing leading to lower capitalisation of a given level of educational quality. The problem with such an explanation, applied at the within city level, is that it would require that the urban housing market would in some sense be in disequilibrium: residents would be able to 'buy' a given quality of education at a lower price in areas of new construction than they could elsewhere.

A second possible reason why there might be a discount in areas of new construction in cities in southeast England is that the planning system operates in such a way as to concentrate new development in localities with disamenties of some sort. Development in such areas generates less opposition from local residents. If these disamenities are not captured in the hedonic then the specification error may result in a reduced level of estimated capitalisation.

A third explanation arises due to the potential for greater uncertainty with respect to future school quality in rapidly growing areas. This uncertainty arises from two sources. First, school quality is sensitive to both the quantity and quality of student intake. Both of these may exhibit greater variance in peripheral areas of new construction. Therefore, house buyers may be uncertain as to the exact quality of schools that will be available to them. They would then discount the amount they are willing to pay for current school quality to reflect this risk. Second, the designation of school catchment areas in neighbourhoods in which new construction is concentrated is likely to be subject to greater and more frequent change as LEAs try to equalise school intakes. This would add an additional source of uncertainty both as to school quality and the distance to be travelled to school because there is less certainty about the school to which a given address in such peripheral areas will be assigned.

Measuring the level of subjectively perceived risk is likely to be difficult. Information is available to house buyers from a variety of sources. If home buyers are acting rationally, that they would be influenced by the variability of the quality measures for the schools to which their children would be assigned, and one might expect such a factor to be relevant regardless of the source of potential variability in school quality. Models V and VI include the standard deviation of our school quality measures over the years 1996-2001 as an additional explanatory variable for all observations. This period covers the time from which data would have been directly available to house buyers, and extends somewhat later to capture the eventual playing out of factors that may have been common knowledge to market participants at the time the house prices were being negotiated. If variability is interpreted as implying a greater risk, current school quality measures will be discounted and we should expect a negative sign on the standard deviation.

There is a further factor that one might expect to influence the capitalisation of school quality into house prices. In any area there may be some houses whose structural characteristics or location make them less suitable for families with children. Such structures will tend to be purchased by households with no children and little willingness-to-pay for local school quality. It would not be rational to pay a premium for good local schools if the dwelling is unable to accommodate children.

Unfortunately, "suitability for children" is not an easily observed characteristic in most housing data, and our data for 1999/2000 does not contain matching demographic information on the household occupying the sampled houses. Instead, we have made use of a 1993 data set for the same housing market that does contain such data. Using these data it was possible to estimate the probability of there being children of school age present in a household as a function of the characteristics of the house: the relevant characteristics determining this probability were the number of bedrooms and bathrooms, the type of house (whether is was semi-detached), the size of the plot on which it was built and the distance the house was from the city centre. A logit model for the presence of school age children was estimated using these data and the parameters were used to generate estimates of the probability of children being present in each house in our 1999/2000 sample (thus indicating its suitability for children).[14]

Both Models V and VI also contain a variable for the ethnic mix of the neighbourhood[15] and for peripheral areas of new construction. In Model V in Table 3, this has the form:

$$\frac{P^{\psi}-1}{\psi} = K + \sum_{i \in D} \beta_i \cdot q_i + \sum_{j \in C} \beta_j \cdot \left(\frac{q_j^{\lambda_1}-1}{\lambda_1} \right) + r(x,\theta) \frac{L^{\xi}-1}{\xi} + \underbrace{\sum_{k \in E} \beta_k \cdot \pi \cdot (1+\beta_P \cdot \delta) \cdot \left(\frac{q_k^{\lambda_2}-1}{\lambda_2} \right)}_{\text{Periphery and Educational Quality}} \quad (3)$$

where all variables are as defined above, and in addition:

β_P = parameter to capture the differential impact of educational quality at the periphery

π = estimated probability that there are school-age children living in the house

δ = dichotomous variable taking the value 1 for houses located in peripheral areas of new construction, and 0 otherwise

Note that the set *E* of indices of variables measuring educational quality now includes measures of the standard deviation in test scores. Model VI simply uses the dichotomous variable δ as a separate characteristic so it acts as a shift dummy for houses located in peripheral growth areas. Thus the hedonic price function is almost the same as equation (3) with a change in the final additive term:

$$\frac{P^{\psi}-1}{\psi} = K + \sum_{i \in D} \beta_i \cdot q_i + \sum_{j \in C} \beta_j \cdot \left(\frac{q_j^{\lambda_1}-1}{\lambda_1} \right) + r(x,\theta) \frac{L^{\xi}-1}{\xi} + \underbrace{\beta_P \cdot \delta + \sum_{k \in E} \beta_k \cdot \pi \cdot \left(\frac{q_k^{\lambda_2}-1}{\lambda_2} \right)}_{\text{Periphery and Educational Quality}} \quad (4)$$

This allows us to test whether any discount strictly relates to school quality or just reflects unmeasured negative effects (disamenities) in such areas.

The results reported in Table 3 are highly informative. All the school quality variables are correctly signed and significant at at least the 10% level. There is strong evidence of current school quality being discounted for risk as measured by the standard deviation of the quality

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[14] The probability of school age children being present in the house was calculated as $\pi = \frac{\chi}{1+\chi}$ where $\chi = e^{-2.05+0.656 \cdot \text{bedrooms}-0.846 \cdot \text{baths}+0.772 \cdot \text{semi}+0.00076 \cdot \text{area}+0.00077 \cdot \text{distance}}$. Appendix Table 2 reports details of the estimation of this relationship.

[15] This is measured as the percentage of the census ward population which was of Afro-Caribbean descent in 1991. It is not significant but it does not adversely affect the estimated parameters for other variables. It is discussed in the Introduction to this Feature.

measures for each school over five years; and the capitalised value associated with a given level of school quality rises in proportion to the suitability of the structure for accommodating children. At the same time the value attached to the features of a house that make it more suitable for children – notably bedrooms – tends to be reduced. More bedrooms are mainly valued because they are useful for accommodating children in locations which will get them into better schools.

Estimates of Model V show that there is indeed a strong discounting of school quality in wards where new construction was concentrated. Since this model outperforms Model VI in which the shift dummy for peripheral new construction areas is not significant, we can safely conclude that the discounting relates strictly to school quality rather than to the areas' amenity levels. The estimated co-efficient for $\beta_{Periphery,}$ indicates that for houses located in the peripheral areas of new construction the value of educational quality is discounted by more than 40% relative to houses in other parts of the city. This is a substantial discount, especially given the fact that the systematic risk associated with variability of school quality is separately accounted for by the inclusion of its standard deviation. Given our scepticism as to the likelihood that purely local elasticity of supply of housing could be the explanation (because it would imply a given level of school quality had a lower price in areas of new construction than it had elsewhere in the same housing market) it seems most plausible to attribute this to concentrated new construction imposing a further risk on local inhabitants: catchment area boundaries in such areas become more subject to revision leading to an additional source of uncertainty for local residents as to which school their children will be assigned and so to the relevant measures of current school quality.

6. Conclusions

In this paper we have sought to show that while average measures of the price of school quality estimated over many communities may be useful, because of variation in the characteristics of the supply of school quality, one should expect that there would be substantial variation in the capitalised value of school quality between and even within cities. In addition we have highlighted what we see as the need to have as completely specified an hedonic model as possible if one is to obtain accurate measures of the capitalised value of school quality.

Applying such an approach to the city of Reading in South East England for data relating to 1999/2000 we find that the quality of both local secondary and primary schools was capitalised into house prices. The statistical significance of secondary schools was considerably greater as was the relative price that secondary school quality commanded. However there are far more primary schools and the range in their performance is considerably greater. Thus there was a larger total impact on house prices associated with 'moving' a standard house from the worst to best primary school catchment area than there was in the case of a similar move between secondary school catchment areas. The price paid for school quality was substantial and, in the case of secondary schools for which a direct comparison is possible, comparable to estimates for both 1984 and 1993 in the same housing market.

Four further conclusions emerged. The first was the need to include (at least in markets where school catchment areas are non-porous) the quality for the actual school to which a house is assigned rather than the quality associated with the nearest school. Indeed there was only a low correlation between the quality measures for the two. The second is the danger of obtaining an upwardly biased measure of primary school quality if as full a range of local neighbourhood characteristics and amenities as possible is not included. Simply omitting the employment deprivation index for the local ward from the model increased the absolute value of the parameter estimate for primary school quality sevenfold (while reducing that of secondary schools).

The third conclusion is that there is evidence strongly suggesting that it is not so much measures of current school quality which are capitalised but of *expected* school quality. There is a significant discount associated with past variability of school quality. School quality also appears to be significantly and additionally discounted in areas in which new construction is concentrated. While this finding is consistent with the hypotheses of Hilber and Mayer (2002) and Brasington (2002) that the elasticity of supply of housing will influence the extent to which school quality is reflected in house prices, both our findings and theirs are capable of other explanations. In our judgement the most plausible interpretation – certainly for our observed within city rather than between cities discount - is that the it reflects uncertainty as to future changes in school catchment areas in such neighbourhoods and so uncertainty as to what school an address will in future be assigned. We regard this as the most plausible explanation both because of the unlikelihood that one could 'buy' a given school quality more cheaply in some neighbourhoods than others within the same housing market and because we do find strong evidence that there is a price discount for uncertainty. The additional uncertainty associated with re-drawing catchment areas (which increases the uncertainty as to which school an address will be assigned) is not directly included but is likely to be concentrated in peripheral areas of new construction. Our results do show, however, that it is unlikely that the discount in such areas reflects the influence of omitted local disamenities from the model since it attaches strictly to school quality rather than to the area itself.

Finally our results also provide strong evidence that the capitalised value of a given level of school quality is a positive function of how good a family nest a particular house provides. School quality commands a higher price in houses better adapted for children. This is not a surprising finding but, unlike in theoretical work, in applied economics it is particularly gratifying to find evidence of the predicted but difficult to measure!

In more general terms the results reported here confirm findings that access to better schools, whether provided free from taxation or through the market, is still conditioned on income. Schools may be ‘free’ but poorer households still face an income constraint on access to quality education, except that it operates through the market in housing rather than through the payment of school fees.

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Appendix Table 1: Correlations between school quality variables

Variable	Price	GCSE Assigned	GCSE Closest	Keystage2 Assigned	Keystage2 Closest	Dist Assgn Pri	Dist Close Pri	Dist Assgn Sec.	Dist Close Sec.
Price	1.000	0.138	0.182	0.202	0.215	0.089	0.142	-0.079	-0.146
GCSE Assigned Secondary		1.000	0.435	0.450	0.409	0.163	0.203	0.264	0.168
GCSE Closest Secondary			1.000	0.412	0.475	0.065	0.017	0.031	0.120
Keystage2 Assigned Primary				1.000	0.815	0.137	0.104	0.095	-0.067
Keystage2 Closest Primary					1.000	0.104	0.071	-0.006	-0.109
Distance Assigned Primary						1.000	0.518	0.435	-0.069
Distance Closest Primary							1.000	0.285	-0.007
Distance Assigned Secondary								1.000	0.544
Distance Closest Secondary									1.000

Appendix Table 2: Presence of School-Age Children

Logit model for children in household		
Variable	**Estimate**	**t-value**
Constant	-2.04553	-3.98
Bedrooms	0.65621	4.11
Baths	-0.84646	-2.65
Semi	0.77168	2.86
Square Meters	0.00076	1.85
Distance	0.00077	1.23
Observations	345	
% Correct	64.058	
LR Chi-square	48.3148	