Capitalising the Value of Free Schools: The Impact of Land Supply Constraints

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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, 2001), which estimates the way in which school quality is capitalised into house prices. In earlier work the present authors (Cheshire & Sheppard 1995; 1999) estimated a hedonic model for the housing markets of Darlington, Nottingham and Reading in the UK in which the quality of the secondary school to which a household was assigned was a significant variable. The more recent work measured secondary school quality using a continuous measure of exam success. This provided evidence that the value of secondary school quality was being capitalised into the price of houses.

In contrast Gibbons and Machin concluded that primary schools had an identifiable and significant price associated with their quality but that secondary schools did not. Their study did not have data for individual houses but used post-code sector data and then various techniques to standardise for all but one variable: either the notional primary school catchment area or the notional secondary school catchment area.

All of these analyses are predicated on the assumption that the value of local schools should be reflected in the value of houses. We 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. This will vary systematically between and even within cities and this paper explores the sources and impact of such variations.

Using an hedonic model and data from 1999-2000, we estimate values attached to both secondary school and primary school quality in the Reading housing market. The results support the conclusion that both secondary and primary school quality is capitalised into the market price of houses and that the capitalisation of school quality is discounted within the highly constrained city of Reading in areas where new construction is concentrated . We also find evidence that appropriate model specification is imperative since bias is evident both when key neighbourhood characteristics are omitted and if the actual allocation of addresses to schools is not included.

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 take up residence in such areas will face reduced educational opportunities, and that fact continues to generate controversy.

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 land use planning policies.

At least three 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 other two 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 particularly 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

[1] We would like to thank the Leverhulme Foundation for its support for the work underlying this paper.

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 least as important as the characteristics of the structure itself in determining market price.

Because 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 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). Both the 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 which are correlated with the school districts then there would be bias in the estimated value assigned to schools. In a fully specified hedonic model however we can (and should) undertake tests of model specification.

Gibbons and Machin (2001) develop another variant on hedonic analysis. They employ a kernel-based technique to try 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. 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, will vary systematically by location within cities reflecting the quite local elasticity of supply of housing (the implications of which are explored by Hilber and Mayer 2001). Thus the resulting estimates will be, at best, mean values for the whole area analysed (in the case of Gibbons and Machin, England and Wales) and may conceal very large variation between areas. Indeed it is perfectly possible that in a British context, in some areas primary school quality is expensive (mainly because it is in inelastic supply) whereas in others, secondary school quality is expensive.

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, any failure to fully 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, giving a double boost or upward bias to the estimated value of primary school quality.

For these reasons 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 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.

2. Considerations of supply

There remains the important issue of supply. Demand and the willingness to pay for school quality may not vary greatly from one city to another, at least within the same country, but its price may vary because of variation in the supply of school quality available to a household living at a specific address. This can vary substantially from one city to another. An important source of such variation will be institutional differences, including land use regulation. If in one location the supply of houses is fixed whilst it is highly elastic in another, then the measured impact of capitalisation of school quality vary even though demand is invariant. This implies the possibility of local variation in the implicit price of school quality.

Even restricting attention to a single country with a common educational and planning system, we should expect substantial differences in the supply characteristics of school quality between cities. Rather less obviously there may be differences in the supply of school quality within cities, especially in larger ones, because of differing elasticities of supply of housing according to location. In previous work (Cheshire and Sheppard, 1995) we have 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.

In the present paper we focus on the particular case of Reading, England. The data set is discussed in the next section but it is important to consider the detailed factors that will influence the supply of school quality within the urban area. First, of all English cities, it is one of the most tightly restricted by growth boundaries. Thus there is likely to be a relatively inelastic supply of housing in the whole area but housing supply will vary from location to location as particular parcels of land are released.

It is a relatively high-income community, well endowed with private schools, particularly at secondary level. This suggests there is likely to 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 secondary school quality. Access to high quality public schools (in Reading) is tightly rationed by location. At the primary school level (i.e. for children below the age of 11) there are in addition state-funded parochial schools, admission to which is more loosely related to home address.

Table 1: Success rate of Appeals against School Allocation and per Appeal

Authority	**Primary Schools**								**Secondary Schools**							
	1997-98		1998-99		1999-00		Mean		1997-98		1998-99		1999-00		Mean	
	Succ[1]	Flex[2]	Succ[1]	Flex[2]	Succ[1]	Flex[2]	Succ[1]	Flex[2]	Succ[1]	Flex[2]	Succ[1]	Flex[2]	Succ[1]	Flex[2]	Succ[1]	Flex[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
Gtr. 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

In addition to private and parochial schools, a further option that might limit the extent of capitalisation of school quality into house prices is the possibility that a household is granted permission to send their children to a state-supported school other than the one to which the house would usually be allocated. Essentially, one must be concerned with the overall 'porosity' of school catchment zones. This will be determined by a combination of factors. 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. However the likelihood of parents nominating a different school to the local one will be partly determined 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) do 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 nor on the proportion of such choices which 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. Some of these data are summarised in Table 1.

Patterns are reasonably consistent between LEAs: Darlington has a high rate of successful appeals; 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 which is rather less restrictive that 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 percent of children successfully appeal against their secondary school allocation in the Reading area (one quarter the success rate of Inner London or England as a whole) and 10 percent of appeals are successful – the same as Inner London but half the proportion of England and one sixth that of Cheshire. A further feature of the Reading area (from discussions with LEA officials) and one which may characterise other areas which seek to steer children to their ‘local’ school is that boundaries are revised on a regular basis to try to fill available school places and eliminate spare capacity. The evidence, therefore, strongly supports the conclusion that in Reading most children go to the school determined by the location of their home and the precise boundaries of the catchment areas in force in the year they first go to either primary (at 5 years) or secondary school (at 11) but that this probability is significantly higher at the secondary school level and is very high by the standards of England as a whole.

A second and unusual feature of Reading’s school system is the continued existence of Grammar Schools (secondary schools with entry highly selective according to tested academic ability). It is possible that this means that as well as a price cut-off determined by the price of private schooling, there is also a quality cut-off in terms of capitalised values. Parents of very high ability children who expect them to get into the local Grammar School might be unwilling to pay for school quality by moving to the catchment area of a better, non-selective school, since they expect their child to get into the Grammar School. There might thus be an apparent drop off of school quality-price at the highest level of measured output quality.

Let us summarise the way in which we conceptualise the elasticity of supply of school quality (or at least supply as measured by those variables we are using to capture it) in Reading. 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 parochial school (which as argued by Gibbons and Machin 2001 may have a cost associated with it of conforming to religious requirements) 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 school, probably a parochial one, 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.

A second feature of primary schools however is that there may be a significant distance decay effect with respect to school quality. The cost of sending a child to a more distant primary school is substantially higher than sending a child to a more distant secondary school. Children younger than 10 or 11 will normally be taken to school by a parent. Secondary school children will usually travel to school on their own. Thus there may be a distance cost associated with primary school quality although their catchment areas may be small enough for this not to be significant. We might anticipate a distance decay effect of the price of primary school quality because a better school is better the nearer it is to home.

At the secondary level parents can make similar choices except that in Reading there is a strong constraint against choosing any secondary school (subject to minor qualification in the case of Catholics or Muslims) other than the one in the catchment area of which you live. However unlike the situation in the US, where school district boundaries tend to be stable, in Reading boundaries of catchment areas are deliberately revised annually.

How are these restrictions on choice affected by the land use planning regulations? Development controls in Reading effectively impose a non-price constraint on housing supply and make that supply more inelastic. In the most extreme case, the effective supply of houses in any school's catchment area would be given by the existing stock. In this situation, we would expect to see complete capitalisation of the value of educational quality into house prices.

Recent analysis by Hilber and Mayer (2001) has drawn attention to the fact that the extent of capitalisation is reduced in areas where the supply is more elastic. Comparing across cities in Massachusetts, they find empirical support for the observation. It is possible that such reduced capitalisation might exist also in those portions of an urban area where land has been released by the planning system and new house construction is allowed although any discount observed may also be attributed to uncertainty about the quality of school a child will attend (because of larger and more frequent changes in the boundaries of catchment areas and uncertain composition of the schools) rather than purely localised differences in elasticity of supply. Finally, if such a discount in the price of school quality is observed it could be due to a land use planning system that works to concentrate new construction in localities with significant local disamenities which are difficult to measure and control for in the hedonic model. In this case any apparent discounting of school quality might in part or whole reflect the spatial concentration of such omitted variables.

3. Data and Setting

Our data are drawn from the urban area of Reading, England. The city is located on the Thames about 35 miles west of central London. Reading is subject to considerable pressure for growth and residential development, and in response 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[2] 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 percent 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.

In 1991 the city had a metro area population of approximately 337000 persons comprising 129000 households. At the time of the 1999/2000 survey we estimate that there were 131370 households. 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 17 months covered by the data. 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.

Supplemental information on land use was assembled from Ordnance Survey resources and aerial photographs. Data on both secondary and primary school catchment areas was obtained from the local education authorities. Data on state-supported school quality were obtained from the Department of Education website[3]. The measure used for primary schools was the performance of its pupils on the Key Stage 2 tests[4]. 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[5]. Data on the availability, performance and price of local private schools was 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

[2] Microsoft, Oracle, Hewlett-Packard and others
[3] http://www.dfes.gov.uk/statistics/DB/SBU/b0333/index.html
[4] 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.
[5] A nationwide exam taken at minimum school leaving age, 16.

characteristics of the neighbourhood. Appendix Table 1 provides some descriptive statistics for the sample and description of each variable used in the analysis.

4. The Hedonic Model

Our basic model follows the principles set out in Cheshire and Sheppard 1995 & 1998. We 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: land value must increase or decrease at the same rate in any given direction away from the urban centre.

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

where:

P	=	sales price of structure
q_i, q_j	=	structure and location-specific characteristics
K, β_i, λ_i, ψ, ξ	=	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 defined below

and the land rent function is given by:

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

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

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 land value function is illustrated below in Figures 1 and 2. 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.

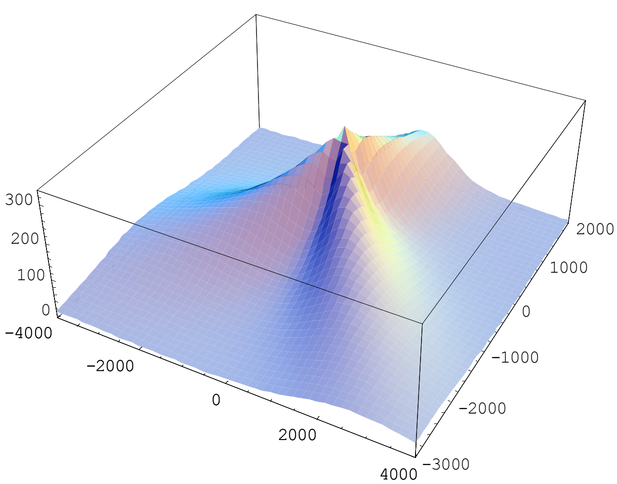

Figure 1 – Plot of land value per acre

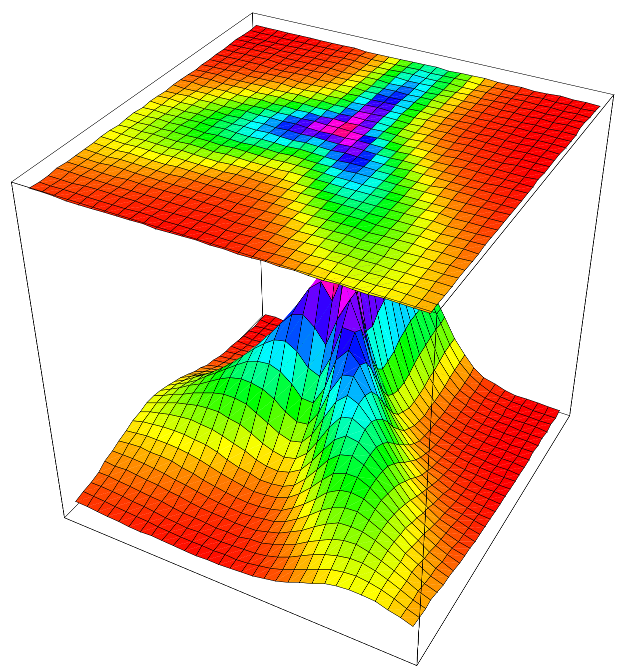

Figure 2 – Land value with projected contours

The measure of the value of land shown in Figures 1 and 2 is essentially the price of 'land as pure space with accessibility'. Actual market prices of vacant land include the capitalized 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 may exceed the value of land as pure space with accessibility[6].

5. Interpreting the results

We present the results of estimation of six models. Parameter estimates for the reported models are presented in Appendix Table 2. 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[7], and Model IV repeats this structure using the school quality measures from the nearest schools. The last two models include all available variables plus 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 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.

A. Value of Primary and Secondary Schools

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 with the data sample used for this analysis) 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 Appendix Table 2 shows immediately 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 standardize the ranges of the quality measures. Figure 3 presents plots of the hedonic price (in thousands of pounds[8]) for both the

[6] In the data studied in Cheshire and Sheppard (1998) the amenity values were greater by a factor of up to eight.
[7] Various 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 shown here.
[8] Evaluated for a house whose value and other characteristics are equal to sample mean values.

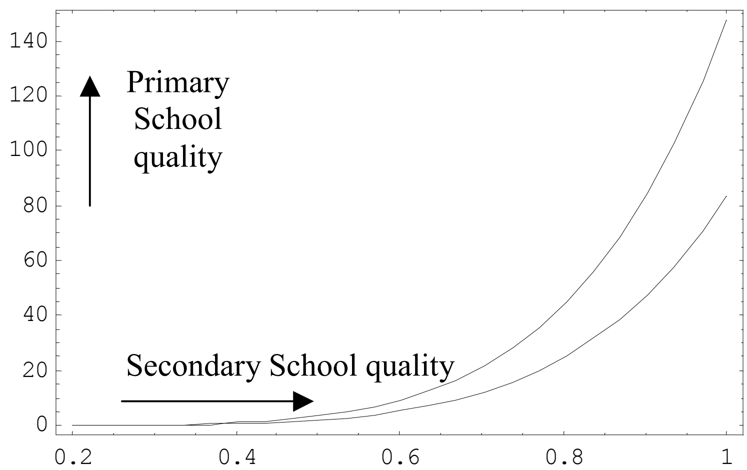

Figure 3 – Comparison of price of quality

measure of secondary school and primary school quality, standardized 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.

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. The movement from the 'best' to the 'worst' secondary school within the area may be a much different proposition than the movement from the 'best' to the 'worst' primary school. Indeed, this is confirmed by considering the change in value of an average house (a house with all characteristics set to sample mean values) as we move from the lowest to highest measured quality in the sample. Figures 4 and 5 provide one way of examining this issue. Each figure shows the variation in the predicted value of the average (bottom curve) and the most expensive (top curve) house in the sample as school quality varies from the lowest observed level to the maximum possible (the vertical axis in both cases is measured in thousands of pounds).

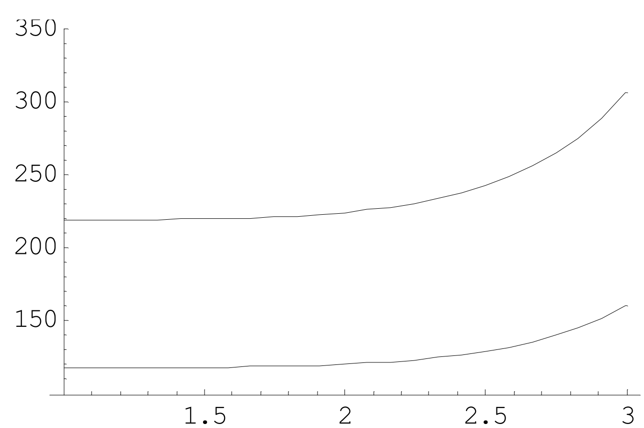

Figure 4 – Impact of primary school quality

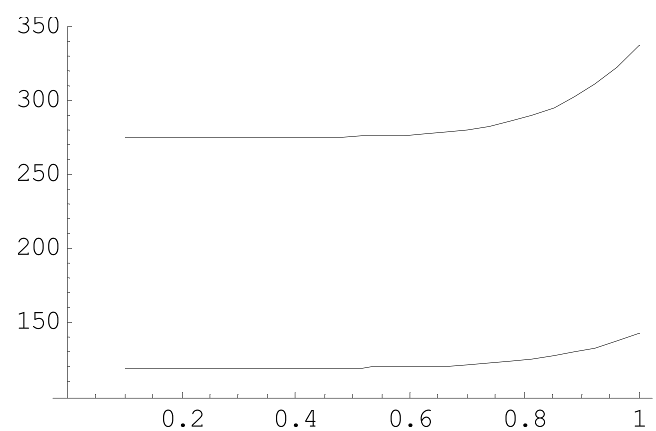

Figure 5 – Impact of secondary school quality

Figures 6 and 7 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. Figure 6 provides a surface that illustrates the impact on house values of changes in both primary (Key stage 2) and secondary (GCSE) school quality. Figure 7 superimposes this surface over a 'histogram' that shows the share of sample observations within each range of qualities. 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 school quality levels.

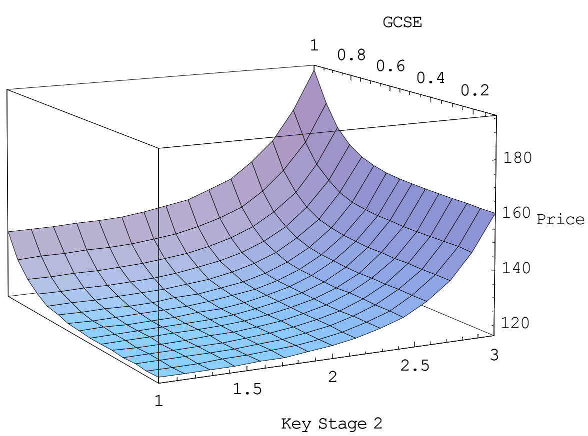

Figure 6 – Impact of quality on house price

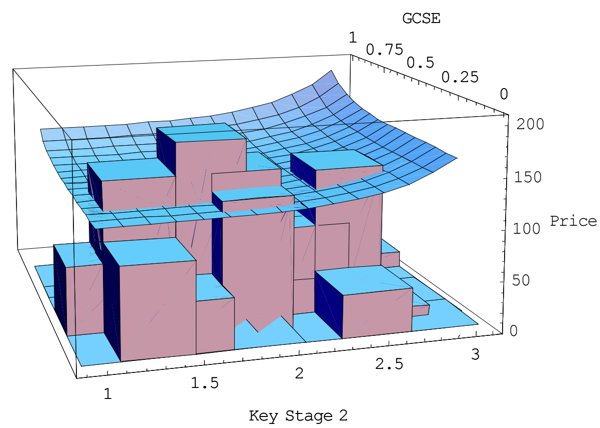

Figure 7 – Impact and distribution of quality on price

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 percent 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 percent of the mean house value). In passing it may be noted that the estimated value added to the price of a mean characteristics house moving it from the catchment area of the worst to the best secondary school from the 1993 sample was an increase of 14.1 percent (Cheshire, Monastiriotis and Sheppard, 2000). The hedonic model used for the 1993 data did not include primary school quality since Key Stage 2 test results were not available then.

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

Determination of the exact school that a child living in a particular house would by default attend is up to the local education authority. This information is not available from any central source, and for some education authorities can be difficult to obtain. For this reason many studies of the effects of school quality 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, a question remains concerning whether this provides a good approximation of the school quality that would actually be available to the residents of a particular house.

Appendix Table 3 shows the correlations between school quality variables. 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 R is only 0.435. Comparing the estimated parameters for models I and II (shown in Appendix Table 2) 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. At least within the sample underlying the present analysis, the nearest school is at best a weak approximation of the school quality actually available to a child who attends the school designated for him or her by the local education authority.

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 local neighbourhood effects. Therefore omitted variables, particularly those related to neighbourhood quality, may bias the estimates of the value of educational quality and such estimates will reflect both the value of education and the value of the omitted neighbourhood variables. To examine this issue we examine the effect of model estimation when the DETR employment deprivation index variable is dropped from the model. This variable provides a measure of concentration in the neighbourhood (census ward) of persons 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 support for the conclusion 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 at the Urban Periphery: Planning for Growth or Uncertainty?

Finally, we turn attention to the possibility that the value of educational quality is not fully capitalised into houses located at the urban periphery. As mentioned above, there are three potential reasons why this might . Under a very restrictive regime of land use regulation such as that observed in the Reading area there would be greater elasticity in the supply of developable land in those areas of the periphery subject to land release. This implies that some of the increased demand for housing is accommodated by increases in supply, so that the price need not rise by the full increase in consumer willingness to pay for access to high quality schools. On the other hand this would imply that in some sense the local housing market was in disequilibrium with residents able to 'buy' a given level of school quality more cheaply in the areas of new construction than they could elsewhere. A second possibility is that the planning system operates in such a way as to concentrate new development in localities with disamenties not all of which are measured in the models.

A third explanation, and the one that seems most plausible, arises due to the uncertainty regarding 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 considerable variance in peripheral areas experiencing rapid development. Therefore, house buyers may be uncertain as to the exact quality of schools that will be available to them. They would therefore discount the amount they would pay for school quality to reflect this risk. A second reason for discounting school quality in neighbourhoods where new development has been concentrated is the likelihood that the designation of school catchment areas will be subject to greater and more frequent change as the education authority seeks to equalise school intakes.

To see if such discounting appears to be present in Reading, we estimate two modified hedonic models. One of the models, V, has the form:

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

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

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

δ = dichotomous variable indicating location in a peripheral area with new housing construction

The second, Model VI, simply uses a dummy variable for houses located in peripheral areas of new construction. This allows us to test whether any discount strictly relates to school quality or just reflects unmeasured negative effects (disamenities) in such areas. 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 clearly outperforms Model VI we can safely conclude that the discounting relates strictly to school quality not to the areas' amenity levels. This discounting is reflected in the variable $\beta_{Periphery,}$ whose value indicates that for houses located in the peripheral areas of new construction the value of educational quality is discounted by more than 60% relative to houses in other portions of the city. This is a very large discount, and given the fabled restrictiveness of UK planning policies is unlikely to be entirely due to supply response. It seems plausible that this arises due to both uncertainty regarding future quality and supply response. Further research is required to isolate the separate contributions of each factor.

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 local variation in the supply of school quality, one should expect that there would be substantial variation in the capitalized 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 capitalized 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 capitalized 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 1993 in the same housing market.

Three further conclusions emerged from this analysis. The first was the need to include (at least in the context of Reading where children are assigned to schools according to their home address) the actual school catchment areas 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 is that evidence was found that school quality measures are significantly discounted in areas in which new construction is concentrated. While this finding is consistent with the hypothesis of Hilber and Mayer (2001) 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. The discount might reflect uncertainty as to future changes in school catchment areas in such neighbourhoods or uncertainty as to what school quality will actually be since catchment areas and intakes are subject to greater change. Our results do show, however, that it is unlikely that the discount reflects the influence of omitted local disamenities from the model since it attaches strictly to school quality rather than to the area itself. The two plausible explanations are not mutually exclusive – both could be true. An important goal of continuing research is to find techniques of distinguishing them.

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Appendix Table 1: 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 lot is within 150 m of Thames
Rail	0.1104	0.3138	0	1	1 if centre of lot 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 lotsize to perimeter
SqFt	676.1154	242.1323	189.8611	1749.0139	Square feet of internal living space in house
Industry	10.6827	11.7065	0	50	Percent of land within 1 km square in industrial use
EmployDepriv	7.0933	2.2435	2.4418	10.2846	DETR index of employment deprivation
Lotsize	222.6534	214.7078	22.1088	2054.5471	Lotsize 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 keystage 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 keystage 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)
Periphery	0.0944	0.2926	0	1	1 if Property located in peripheral ward with new construction

Appendix Table 2: Estimated parameters for Models I to VI, with t-statistics for each estimate.

Parameter	Model I	Model II	Model III	Model IV	Model V	Model VI
β_0	3.124553	3.236343	3.336312	3.29032	3.157533	3. 046134
t	*29.601*	*11.183*	*31.084*	*16.088*	*13.259*	*8.763*
$\beta_{Detached}$	0.185303	0.201205	0.238915	0.224075	0.196929	0.206525
t	*8.469*	*4.751*	*12.608*	*6.321*	*4.472*	*3.551*
$\beta_{Semi\text{-}detached}$	0.119002	0.134669	0.150193	0.14736	0.127006	0.133012
t	*6.800*	*4.798*	*9.395*	*6.204*	*4.311*	*3.062*
$\beta_{Terrace}$	0.051215	0.054739	0.066083	0.058462	0.055034	0.056112
t	*4.195*	*3.517*	*5.544*	*4.425*	*3.284*	*2.705*
$\beta_{Townhouse}$	0.07224	0.080601	0.084975	0.081427	0.077399	0.080087
t	*4.868*	*4.201*	*5.853*	*4.648*	*3.480*	*2.951*
$\beta_{Parking}$	0.011386	0.010764	0.01165	0.007322	0.011901	0.012787
t	*1.742*	*1.607*	*1.762*	*1.062*	*1.723*	*1.398*
β_{Thames}	0.074639	0.091209	0.09254	0.107257	0.077876	0.080634
t	*2.339*	*2.487*	*2.991*	*2.825*	*2.453*	*1.775*
β_{Rail}	-0.00837	-0.00985	-0.0076	-0.00957	-0.00899	-0.007828
t	*-0.949*	*-1.052*	*-0.855*	*-1.002*	*-0.990*	*-0.645*
$\beta_{Cul\text{-}de\text{-}sac}$	0.030018	0.03431	0.05332	0.050991	0.034378	0.035039
t	*2.265*	*2.234*	*4.197*	*3.389*	*2.447*	*1.821*
$\beta_{Minor\ Rd.}$	0.005123	0.006463	0.019676	0.018172	0.008648	0.008621
t	*0.452*	*0.565*	*1.749*	*1.559*	*0.763*	*0.580*
$\beta_{B\text{-}Road}$	0.099615	0.109639	0.139194	0.133493	0.110225	0.112372
t	*3.814*	*3.203*	*5.448*	*4.254*	*3.835*	*2.681*
$\beta_{A\text{-}Road}$	-0.0013	-0.00385	0.024584	0.011935	0.002416	-0.000335
t	*-0.071*	*-0.227*	*1.381*	*0.679*	*0.139*	*-0.0149*
$\beta_{TimeTrend}$	0.029917	0.034401	0.037374	0.041336	0.030265	0.034544
t	*3.185*	*2.931*	*4.153*	*3.862*	*2.849*	*2.526*
$\beta_{Bedrooms}$	0.02032	0.024127	0.027871	0.025885	0.022862	0.020019
t	*3.031*	*2.955*	*3.939*	*3.619*	*2.578*	*1.710*
$\beta_{Bathrooms}$	0.051009	0.055213	0.061564	0.062694	0.054531	0.062154
t	*6.320*	*4.717*	*8.261*	*6.458*	*5.838*	*3.871*
$\beta_{Notsquare}$	0.04914	0.052667	0.063436	0.053442	0.054138	0.053714
t	*2.848*	*2.469*	*3.579*	*2.745*	*2.567*	*1.973*
β_{SqFt}	0.007772	0.005708	0.005827	0.007122	0.00716	0.015597
t	*18.951*	*6.457*	*21.543*	*10.140*	*7.592*	*4.733*
$\beta_{IndustrialLand}$	-0.00113	-0.0014	-0.00137	-0.00214	-0.00067	-0.000832
t	*-1.663*	*-2.071*	*-2.083*	*-2.780*	*-0.801*	*-0.758*
$\beta_{EmployDepriv}$	-0.02416	-0.02372			-0.0113	-0.016711
t	*-5.899*	*-6.048*			*-4.836*	*-5.326*
$\beta 1$	0.00766	0.009199	0.001622	0.001981	0.006044	0.005016
t	*1.352*	*4.447*	*5.059*	*1.577*	*1.221*	*1.587*
$\beta 2$	-0.00095	-0.00097	-0.00141	-0.00108	-0.00099	-0.000917
t	*-3.148*	*-3.502*	*-2.349*	*-2.610*	*-3.756*	*-2.738*
$\beta 3$	0.000516	0.000485	0.001067	0.000606	0.000541	0.000498
t	*1.953*	*2.190*	*1.724*	*1.647*	*2.210*	*1.745*
$\beta 4$	-3.79069	-3.87525	-3.9581	-4.07902	-3.85198	-3.91983
t	*-23.445*	*-21.723*	*-21.876*	*-17.254*	*-23.113*	*-21.381*
$\boldsymbol{\beta_{PrimarySchool}}$	**0.000836**	**0.000971**	**0.005957**	**0.002127**	**0.000593**	**0.003342**
t	*2.461*	*1.384*	*1.854*	*1.656*	*2.694*	*2.732*
$\boldsymbol{\beta_{SecondarySchool}}$	**0.588393**	**0.335556**	**0.474515**	**0.513499**	**0.278866**	**-0.339676**

Parameter	Model I	Model II	Model III	Model IV	Model V	Model VI
t	*6.215*	*4.766*	*4.212*	*3.557*	*3.507*	*-1.152*
λ_1	0.500048	0.551618	0.576605	0.531902	0.521684	0.419329
t	*24.429*	*9.681*	*48.943*	*13.406*	*10.544*	*6.311*
λ_2	6.445736	6.508272	4.710182	6.026819	7.101111	4.938933
t	*11.943*	*8.204*	*7.628*	*8.719*	*15.255*	*5.554*
ξ	0.417822	0.425036	0.73667	0.737899	0.482328	0.531631
t	*2.257*	*4.063*	*9.434*	*5.473*	*3.633*	*4.067*
Ψ	-0.14056	-0.1213	-0.09503	-0.10093	-0.12659	-0.111524
t	*-7.913*	*-2.794*	*-8.552*	*-3.568*	*-3.309*	*-2.156*
$\beta_{Periphery}$					-0.60186	-0.002997
t					*-1.925*	*-0.172*
σ	0.075256	0.082311	0.095002	0.092192	0.079578	0.085398
	10.913	*4.735*	*18.492*	*6.946*	*5.145*	*4.025*
Log Likelihood	-2103.11	-2101.9	-2110.45	-2109.55	-2097.26	-2096.95
N	490	490	490	490	490	490

Appendix Table 3: Correlations between school quality variables

Variable	Price	GCSE Assigned	GCSE Closest	Keystage2 Assigned	Keystage 2 Closest	Distance Assigned Primary	Distance Closest Primary	Distance Assigned Sec.	Distance Closest 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