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Houses and Schools: Valuation of School Quality through the Housing Market

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Stephen Machin

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Houses and Schools:
Valuation of School Quality through the Housing Market

Stephen Machin

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Abstract
This paper offers a critical appraisal of the now sizable empirical literature that values school quality and performance through housing valuations. This literature consistently finds housing valuations to be significantly higher in places where measured school quality is higher, implying a strong parental willingness to pay to get their children educated in better performing schools. This conclusion emerges from studies undertaken in a number of countries, using a variety of identification strategies, and at different parts of the education sequence that children follow.

Keywords: house prices, school quality
JEL Classifications: H4, R21

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Stephen Machin is Research Director and Programme Head of the Labour Markets Programme at the Centre for Economic Performance, London School of Economics. He is also Director of the Centre for the Economics of Education at LSE and Professor of Economics at University College London.

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1. Introduction

Assessing parental willingness to pay for school quality through housing valuations has become a significant research venture (see the reviews by Sheppard, 1999, Gibbons and Machin, 2008, and Black and Machin, 2010). There is now a large literature looking at empirical connections between house prices and observable measures of school quality that concludes parents are prepared to pay significant sums of money to get their children enrolled in what they perceive to be better performing schools.

The usual approach adopted in this work is to estimate empirical models relating house prices to measures of student performance in a hedonic pricing framework. Of course, the use of hedonics is not unique to this area and a long tradition of research in several branches of economics (including urban, environmental, transport and crime economics, among others), has used data on housing expenditures as a means of eliciting the prices of, or willingness to pay for, local amenities (see Sheppard, 1999). However, trying to empirically untangle the part of house prices connected solely to differences in school quality presents its own specific challenges and methodological difficulties.

In fact, the area has been characterised by significant methodological improvements over time. These have in part been facilitated by improvements in data quality, and in part by recognition of the shortcomings of approaches adopted in some of the early work in the area. In this paper I spend some time discussing how these methodological developments have progressed in this research area.

The new empirical approaches raise fresh questions and have pushed the research in new directions. I will therefore also discuss some of the issues addressed in the cutting edge research on housing valuations of school quality, looking in more detail at some of the themes considered in a selected group of recent research papers in the area.

In terms of the overall picture, it is important to note the high policy relevance of this research. All over the world parents are concerned about getting better education for their children and governments are trying to offer better quality schooling in the most cost effective manner they can. Careful discussion of the magnitudes of the house price-school quality relationship uncovered in the empirical work, and their variation across different kinds of households, is thus an important exercise to undertake.

The structure of the rest of the paper is as follows. In Section 2, I discuss the key research questions and empirical issues associated with them. In Section 3, I provide a discussion of the research approaches that have been adopted to attempt to address these issues and give a general overview of the findings of the empirical work in the area. Section 4 chooses to focus in more detail on some of the more interesting features of the newer work, whilst Section 5 concludes.

2. Research Questions and Empirical Issues

Research Aims

The key aim of research in this area is to assess how much, and along what dimensions, parents value better schools. The dominant research approach uses housing market data to calculate how much more parents are willing to pay to live in an area which has a better performing school.

To provide a credible valuation of school quality, the research attempts to compare house prices for the same kind of house in two different locations, which differ only in that one has a better performing school and the other has a less well performing school. The practical difficulty is, of course, that houses and areas are not otherwise identical and so one

needs to carry out careful statistical analysis to accurately pin down the relationship between house prices and school quality so as to separate out that part of the housing expenditure which solely reflects differences in school quality.

A lot of the work begins by placing itself in the context of estimating the demand for school quality in the hedonic analysis of housing markets. Theoretical underpinnings of these kinds of demand equations can be traced back to the seminal contribution of Rosen (1974), from which one can derive empirically implementable models that relate house prices to local amenities of interest.

Studies that derive empirical specifications using hedonics straddle the range from regression-based property value models that relate micro-house prices to local amenities in a reduced form setting, through to those that get closer the estimation of the structural demand and supply parameters of the Rosen model.[1] As the discussion that follows will make clear, in some research these approaches have been relatively successful at credibly pinning down the part of housing expenditure connected solely to variations in school quality but, at the same time, they are also characterised by some modelling difficulties which urges caution and care in the interpretation of results.

Modelling Issues

Using housing expenditures as means of eliciting value has a long history, dating back at least as far as von Thunen (1826) and in the classic urban economics exposition of Alonso (1964). Of course, housing expenditures are determined by many more factors than differences in school quality. To illustrate this, consider Figure 1, which shows house price contours for the Greater London region of the UK in 2002 and 2003 (taken from Gibbons and Machin, 2008). The Figure contains three panels. In the top panel, the map has been drawn by 'smoothing' the prices of houses geographically to pick out the kind of broad mono-centric land value pattern that are consistent with the simplest urban economics models. In these, land prices rise towards the centre of the city (albeit to the west of where we would usually place London's central business district) because central city locations are most highly valued by business, and because residences there provide the lowest-cost access to centrally located jobs and amenities.

The second panel of the Figure focuses in on much more localised price variation (by reducing the degree of 'smoothing' applied to the data in producing the map). It is clear that there is a lot of intra metropolitan price variation that requires other explanations. Part of this localised variation can be put down to local differences in housing quality – but very clearly not all. The third panel adjusts for observable differences in housing size and type, and strong local patterns remain. The main aim in the house price-school quality work is to isolate how much of this localised variation is attributable to parents' willingness to pay for higher school quality.

There are significant empirical challenges in this project. Most notably, the full range of relevant housing characteristics and neighbourhood attributes are never observed by econometricians, so estimates can be plagued by standard omitted variables and endogeneity problems. These complications for empirical implementation can be thought of as manifesting themselves through the nature of data on local amenities that consumers value and through sorting.

There are two principal concerns. The first deals with the endogenous nature of the amenity. Theoretical work (such as that by Nechyba, 2003a, 2003b, and Epple and Romano,

[1] This latter literature is not considered here. Such work is typically not concerned with the estimation of school quality effects *per se*, but more with the estimation of the structural parameters of the Rosen model. This work is often a highly technical nature (see, *inter alia*, Ekeland, Heckman, Nesheim, 2002, 2004, and Tauchen and Witte, 2001).

1998, 2003, or Bayer and McMillan, 2005) describes how voting on public school funding (and hence quality) can be affected by the characteristics of the people in the neighbourhood. In other words, the supply of an amenity like school quality is, at least in part, determined by the socio-economic composition of the community where the school is located. Some of the literature has been limited in its ability to control for this correlation - or the Tiebout (1956) sorting of richer and poorer families into different neighbourhoods characterised by different school qualities.[2]

The second concern is that, because of the strong correlation between neighbourhood characteristics and school quality, estimates of the value of school quality will be biased upward by omitted neighbourhood or house quality characteristics. To the extent that the variables observed by the econometrician are an incomplete set of the characteristics observed by the homeowner (e.g. if as is likely in practice there are other unobserved local amenities correlated with house prices and/or school quality), this is very likely to be a problem. It is therefore important to consider how researchers have attempted to deal with the correlation between neighbourhood characteristics (observed and unobserved) and schools that are observed in the data.

Empirical Implementation

More formally, consider the following equation for house prices (in logs denoted by p) with characteristics $x(c)$ in a geographical location c, as:

$$p = s(c)\beta + x(c)\gamma + g(c) + \varepsilon \qquad (1)$$

In (1) $s(c)$ represents the school 'quality' that home buyers expect to be able to access by residence at c, prior to school admission, measured on the basis of school characteristics at periods prior to the house sale. These attributes can be thought of in a general sense as measures of school composition, resources and effectiveness. The term ε represents unobserved housing attributes and errors that are assumed to be independent of x and c. The function $g(c)$ represents unobserved influences on market prices that are correlated across neighbouring spatial locations, such that the price varies with geographical location, for example due to unobserved neighbourhood characteristics and amenities (other than schooling). Location c can be specified in various ways, most flexibly in terms of a vector of geographical or Cartesian coordinates.

In this setting, ideally we want the estimated coefficient on school quality, β, to reflect the causal impact of school quality on house prices. Various approaches have been taken in the literature to try to best ensure that this is the case. Indeed, there are many estimates of β from studies undertaken in a number of countries, using a variety of identification strategies, and at different parts of the education sequence that children follow. Another part of the literature emphasises that there may be heterogeneity in the estimated house price-school quality relationship so that parental willingness to pay could differ across observable characteristics of families, schools and neighbourhoods (see Bayer, Ferreira and McMillan, 2007). I consider these empirical findings in detail in the remaining parts of the paper.

[2] Indeed, this can become a highly relevant issue in some contexts, like in the US and other countries where local property taxes generate links between housing values and school quality via public expenditure on schooling.

3. Empirical Approaches and Overview of Evidence

Empirical Approaches

Black and Machin (2010) identify six main empirical approaches that have been followed in this research area. These are:

i) regression based estimates;
ii) parametric and non-parametric modelling of unobservable factors;
iii) instrumental variables approaches;
iv) discontinuity methods using administrative boundaries;
v) difference-in-difference, repeat sales and quasi-experimental methods;
vi) combined methods.

Black and Machin (2010) classify fifty-four papers from the literature into these six approaches. Table 1 shows this classification. The bulk of the papers (31 out of 54) used what might be thought of as more conventional methods like using regression methods (least squares, or least squares supplemented parametric or non-parametric modelling of time trends or instrumental variables) to try to control for confounding differences that could bias the estimation of β. The remaining 23 use the more modern methods (described below) that have become prevalent in contemporary empirical analysis in economics.

Methods i), ii) and iii) tended to be adopted in earlier studies. Black and Machin make the judgement that these methods tend to suffer from serious shortcomings connected to the methodological difficulties of omitted variable bias and sorting and, in the case of iii), rather unsatisfactory exclusion restrictions in instrumental variable frameworks.

Methods iv), v) and vi) reflect more recent work in the area which tries to deal seriously with the modelling concerns around estimating from β in equation (1). The boundary discontinuity approach iv) was adopted to try to more carefully isolate the role of school quality from the role of neighbourhood characteristics (Bogart and Cromwell, 1997, and Black, 1999, being the first two path breaking studies doing this). The boundary discontinuity regression method attempts to mitigate the effects of endogeneity induced by unobserved neighbourhood characteristics by looking at house price differences across school admission boundaries. The key argument for identification is that school quality effects on prices can be identified from discontinuities at admission zone boundaries as houses and local amenities should be much the same at either side of the boundary (which often run down the middle of streets), but that children on either side attend schools of varying quality.[3]

Method v) attempts to difference out the unobservables from equation (1) by, for example, comparing housing prices before and after changes in school quality, or taking a more quasi-experimental approach, for example looking at policy driven changes in the provision of school quality like school openings or closures or the introduction, re-drawing or withdrawal of school catchment boundaries. Studies classified under method vi) mix methods more, but tend to have some combination of the better identification strategies in iv) and v).

[3] Similar thinking provides the foundation for studies that have investigated effects of market access when there are changes in national borders or their permeability. Examples include Redding and Sturm (2008), who look at changes during German division and re-unification, and Hanson (2004) who focuses on the opening of Mexican border due to the North American Free Trade Agreement. Boundary discontinuities have also been used to assess the effect of taxation on housing prices (Cushing, 1984), and on the location of manufacturing firms (Duranton et al., 2006; Holmes, 1998).

Overview of Findings

When one considers findings from the overall literature, a reasonably clear picture does however emerge. Consider the ten selected studies described in Table 2. Looking at the summary results in the Table, it can be seen that whilst there is certainly some variation in the point estimates from one study to the next, they do fall within a reasonably tight range. The median figure from these studies is about 4%, with an inter-quartile range of 4%. This stability is remarkable considering the diverse international contexts on which the estimates are based and provides some reassurance that the methods are uncovering a fairly universal figure for the valuation of school quality, at least when standardised in terms of percentage value relative to local housing costs.

Approaches using boundary discontinuities have proved popular in recent years, measuring house price differentials between closely spaced properties on either side of catchment area boundaries. The figures generated by this method from Australia, the US and UK tend to be very closely aligned (with one exception), providing a median figure of 3.5% and an interquartile range of just 1.3%. Other methods have, however, produced results that are not far out of line.

An obvious question is whether these figures are plausible as monetary estimates of willingness to pay for school quality. A number of the studies have translated the capitalised values into monetary equivalents: for example, Black (1999) prices a one-standard deviation increase at around $4000 in mid-1990s Boston; Gibbons and Machin (2006) places the figure at about £9000 in London in 2004.

In annualised terms these figures do not seem unreasonable. In 2004 prices the Gibbons-Machin estimates amount to roughly £450 per year in London, at a time when the average per-pupil spend in England's primary schools was £2750. These figures can also be benchmarked against the costs and availability of private schooling, providing some complementary evidence of their validity. For example, Gibbons and Machin (2003) argue that payment for state schools via the housing market does not exceed private school fees for a single child in London, and Fack and Grenet (2010) come to similar conclusions for Paris.

4. Particular Issues of Interest

In this Section three specific areas of interest that the newer empirical work has focussed upon are considered. These, which are considered in turn, are: What do parents value?; heterogeneity in β; and the availability of private schooling.

What do Parents Value?

Most papers in the literature are confined to showing that house prices correlate with headline school performance measures based on school average test scores. However, better school test scores could occur through improvements in school intake or through faster pupil progress – potentially driven by teaching quality, school resources and peer effects. One possibility is that parents pay for school output or value-added because it represents what they expect their children to *gain* academically. A second possibility is that parents pay for good peers and favourable school composition – which are school inputs – irrespective of the likely contribution that these factors make to their own child's achievements.[4] While the first

[4] See Kramarz et al. (2009) for a detailed discussion, together with empirical tests, of the relative importance of pupil, school and peer effects in determining test scores. Their findings suggest that a large part of the variation in test scores is explained by pupil attributes, followed by school quality differentials. On the other hand, peers' characteristics matter less. This result is consistent with Gibbons and Telhaj (2008), Lavy et al. (2008) and most other studies on peer effects.

perspective is interesting from a policy point of view because it puts a price on interventions that raise academic standards, the second one is relevant because of its implications for school segregation (e.g. Epple and Romano, 2003). Clearly then it matters which of these drivers is important in determining house prices.

A handful of papers have taken steps to disentangle these two channels of influence. Brasington and Haurin's (2006) results appear to show that that school value-added and initial achievements both have positive effects on prices, although this important point is lost in their conclusions. Kane et al. (2006) also consider value-added and average test scores as alternative indicators of school performance. However, they do not present specifications that include both indicators simultaneously, and do not aim to provide persuasive evidence on the importance of value-added. In contrast, Clapp et al. (2008) show that pupil ethnicity seems more important than test scores to home buyers around Connecticut schools, although the authors do not have access to data on pupils' academic progress.

Other papers have looked at the importance of school expenditure relative to test score outputs. For example, Downes and Zabel (2002) find that test scores are capitalised into local house prices, whereas measures of school expenditures are not. Very recently, Cellini et al. (2008) use referenda outcomes in California's school finance system to suggest that house prices respond to the level of capital expenditure per pupil and that this cannot be fully explained by changes in test scores.

Occasionally other school attributes have been considered. For example, Figlio and Lucas (2004) find that state-assigned school ratings have a transient effect on prices, over and above test scores, suggesting that householders draw additional information about achievement from these grades, or else value the ratings in their own right. Gibbons and Machin (2006) also suggest that popularity in itself raises prices, given that over-capacity schools command an additional premium relative to under-capacity schools with equal performance. Gibbons and Silva (2011) find that, once school quality is included in the house price equation, there is no significant housing valuation of self reported measures of child well being and parental satisfaction with the school.

One recent study focuses in some detail on the question of what it is that parents value. Gibbons, Machin and Silva (2009) look at valuation of primary school quality in England and generalise the estimating equation (1) to consider the relative importance of two school variables: value added in test scores from age 7 to 11 (*va*) and the initial peer intake at age 7 (*s7*). They also adopt a regression discontinuity boundary approach differencing across local authority boundaries using the following (levels and differences) specifications:

$$\begin{aligned} p_{hi} &= \beta_1 va_i + \beta_2 s7_i + z_i\lambda + x_{hi}\gamma + g(c_i) + \varepsilon_{hi} \\ \Delta p_{hi} &= \beta_1 \Delta va_i + \beta_2 \Delta s7_i + \Delta z_i\lambda + \Delta x_{hi}\gamma + \Delta g(c_i) + \Delta\varepsilon_{hi} \end{aligned} \qquad (2)$$

where p_{hi} is the (log) price of the house sale h in location i, va_i is value-added and $s7_i$ is the mean age-7 test score for schools that can be accessed from location i (measured at periods prior to the house transaction), z_i contains other observable school and neighbourhood characteristics, x_h contains observable attributes of house sale h and the function $g(c_i)$ represents unobserved neighbourhood characteristics and amenities (other than schooling) that affect market prices. $g(c_i)$ can be parameterised using boundary dummy variables, distance to school, distance between matched transactions and various distance-to-boundary polynomials. As usual, ε_i represents unobserved housing attributes and errors that

are independent of all other factors (i.e. 'noise'). The notation Δ means a difference between matched, closest transactions on either side of the LA boundary.

Table 3 reproduces some of their key results. The Table shows estimated coefficients (multiplied by 100 so as to show, to an approximation, the percentage effect of a one point change in school mean test scores) on value added and the age 7 test score from three specifications: column (1) reports results from a simple ordinary least squares (OLS) regression using the full pooled cross-sectional samples for 2002-2006; column (2) shows estimates from the same specification estimated on the boundary sub-sample; and column (3) from the cross-boundary pair-wise differenced model.

It is evident that the preferred cross-boundary estimates in column (3) are typically smaller in magnitude than the column (1) and (2) estimates. Both test score variables attract a significant positive coefficient indicating that parents value both value added improvements and initial test scores. A one point change in *va* leads to a 3.7 percent increase in log house prices and a one point change in *s7* leads to a 2.8 increase in log house prices - in both cases, these correspond to about a 3 percent increase following from a one standard deviation change in *va* or *s7*. The size of these house price responses sits comfortably with previous results in the literature, surveyed above, which shows a consensus estimate of around 3-4% house price premium for one standard deviation increase in school average test scores.[5] Moreover, one cannot reject the null hypothesis that *va* and *s7* are equally valued (see the p-value in the notes to the Table). Thus it is evident that school choice is driven by the demand both for expected academic gain *and* for aspects of expected peer group quality that are uncorrelated with current academic gains.

Heterogeneity in β

An important paper in the housing valuation of school quality literature by Bayer et al (2007) makes the observation that linear regression estimates may not provide estimates of the *mean* valuation of school quality, because the marginal willingness to pay (WTP) for school quality can vary across the distribution of household characteristics. Bayer et al. (2007) builds on Berry et al. (1995) and focuses on this particular identification problem, describing a solution using a two-stage structural approach that imposes a particular functional form on the residential choice and sorting process (coupled with an instrumentation strategy).[6]

The work by Bayer et al. (2007) shows that, both empirically and from a theoretical point of view, the 'traditional' hedonic models are broadly effective at evaluating mean WTP in contexts where the amenity in question is supplied at various qualities in many different locations. The authors find a user cost of housing response of approximately 2.5% for a one standard deviation change in test scores in their 'standard' hedonic models, which rises to around 3% when accounting for the effects of sorting.[7] Interestingly, in the latter case, they emphasise heterogeneity in the marginal WTP that differs systematically with household characteristics. There is considerable variability in their estimates. The mean WTP for a one standard deviation in average test scores is $19.70 per month (in 1990 dollars), or around 2 percent of mean monthly user costs of housing. However, this varies systematically and markedly with race, education and income. For example, they find that college-educated

[5] Gibbons, Machin and Silva (2009) present a large number of robustness tests and falsification exercises to validate these results.

[6] In terms of detail, the first stage in their estimator involves a multinomial logit model on actual housing choices. Although technically impressive, this method relies on strong and hard-to-test assumptions about the shape of the indirect utility function and on the Independence of Irrelevant Alternatives (IIA) hypothesis invoked to estimate multinomial logit models. It is thus somewhat difficult to generalise its applicability.

[7] Bayer at al. consider data on both owner- and renter-occupied housing units in the San Francisco Bay Area and so convert house values to a measure of monthly user costs.

households are willing to pay $58 a month more than non-college educated households to live in a neighbourhood with 10 percent more college-educated households. This implies considerable heterogeneity and sorting.

Caetano (2009) also considers heterogeneity, specifically looking at heterogeneity across different households (e.g. with and without children, or with different aged children), arguing that the marginal WTP will vary across these groups. Using Census data on households in Minnesota, he finds considerable variations. For a 5 percent increase in test scores, parents are willing to pay 11 percent more in rental prices for elementary school, 6 percent for middle school and 12 percent for high school. Thus his estimates display interesting variations across children of different ages at different stages of the education sequence.

Availability of Private Schooling

One final issue of interest is that the literature provides evidence valuing state provided education. However, in most countries, private schooling alternatives are available to parents. Quite a lot of the theoretical work on school quality concerns itself with choices between public and private schooling (see, *inter alia*, Epple and Romano, 1998, Nechyba, 1999, 2004). However, not so much of the empirical work considers this in detail. Fack and Grenet (2010) is an exception where, in their analysis of Paris middle schools, they explicitly argue and test for the notion that the presence of private schools has a mitigating influence upon the house price-school quality association.[8] Their evidence shows significant spatial heterogeneity linked to private school density in the area, in that the effect of school quality is more pronounced for residences in areas with a low density of private schools (and non-existent for areas in the upper quartile of private school density).

5. Conclusions and Future Research Questions

This paper takes the opportunity to critically appraise what has become a major study area amongst economics of education researchers, namely trying to estimate how much parents are willing to pay to get their children into a better performing school. The vast majority of work in the area uncovers a significant statistical association between housing valuations and school quality. This is the case for a reasonably large number of published papers based upon data in a wide range of international contexts with different education institutions.

One striking characteristic of this work in this area has been the clear improvements and refinements of methodology over time. These have led to an increased confidence in the credibility of the findings that school quality is capitalized into housing values. Some of the more recent literature has more carefully explored heterogeneity in the extent of this capitalization and this would seem to offer a significant future research direction, especially as better, more detailed data becomes available. Moreover, this may enable researchers to consider more exactly what features of a school make a "good" school (at least to parents), and possibly advance further the decidedly inconclusive literature on the role of school inputs on student outcomes.

[8] It should be acknowledged that the idea that private school availability mitigates estimates of β is rather different from the focus of the theoretical work that tends to consider the availability of private schooling in different housing markets and, as such, there remains something of a disconnect between theory and empirics in the literature on this issue.

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Figure 1: House Price Contours, London, 2002-2003 (From Gibbons and Machin, 2008)

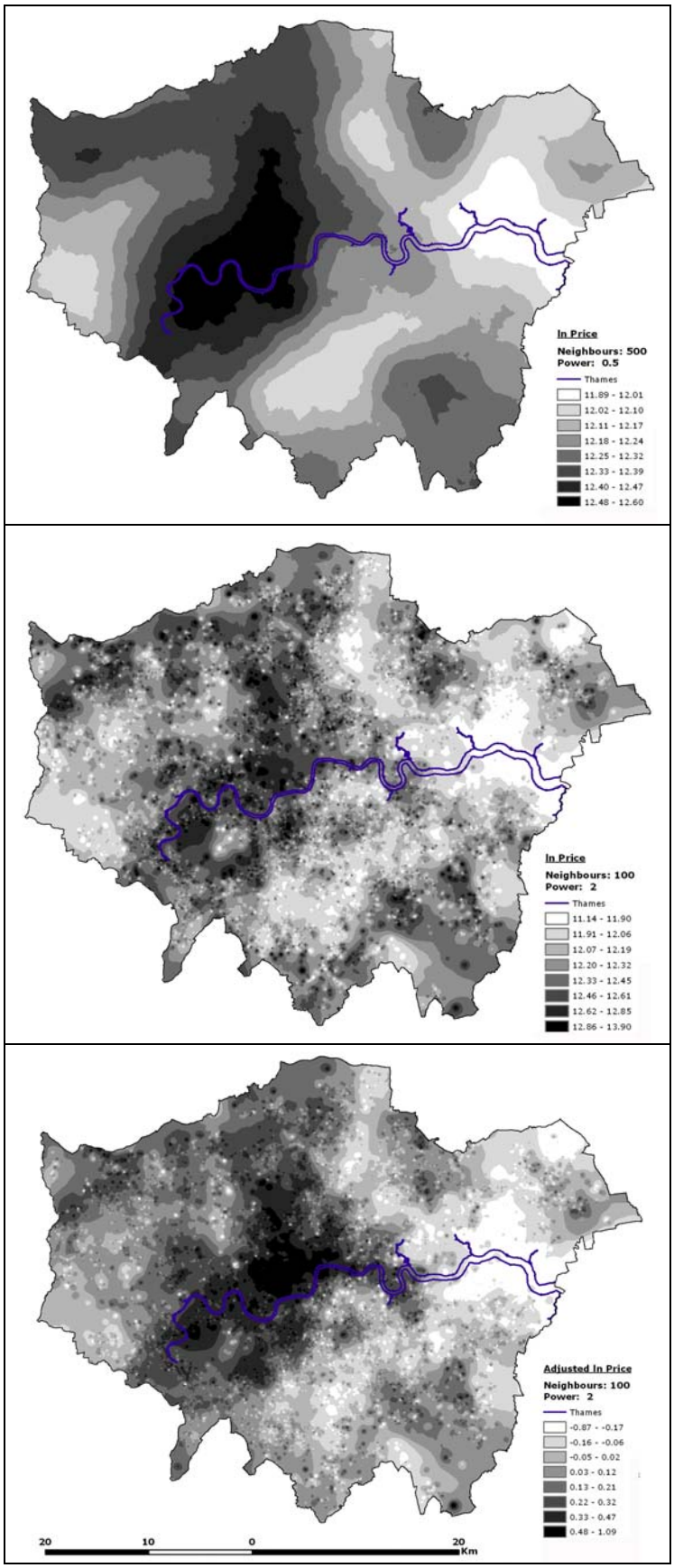

Table 1: House Price and School Quality Papers Surveyed in Black and Machin (2010)

Method	Number of Papers
i) regression based estimates	24
ii) parametric and non-parametric modelling of unobservable factors	4
iii) instrumental variables approaches	3
iv) discontinuity methods using administrative boundaries	6
v) difference-in-difference, repeat sales and quasi-experimental methods	12
vi) combined methods.	5

Source: Black and Machin (2010).

Table 2: Estimates from Ten Selected Studies

Study	Method	Impact on Prices	Data
Brasington and Haurin (2006)	i)	7.6% for 1sd	Ohio, US
Cheshire and Sheppard (2004)	ii)	4-10% for 1 sd	Reading, UK
Rosenthal (2003)	iii)	5% elasticity	England
Black (1999)	iv)	2.5% for 1 sd	Boston, US
Davidoff and Leigh (2008)	iv)	3.5% for 1 sd	Australia
Fack and Grenet (2010)	iv)	2% for 1 sd	Paris, France
Kane, Staiger and Riegg (2006)	iv)	10% for 1 sd	Mecklenberg, US
Clapp, Nanda and Ross (2007)	v)	1.3-1.4% for 1 sd	Connecticut, US
Bayer, Ferreira, McMillan (2007)	vi)	1.8% for 1 sd	SF Bay, US
Gibbons and Machin (2003, 2006)	vi)	3.8%-7% for 1 sd	London, UK

Table 3: Ordinary Least Squares (OLS) and Cross-Boundary Differenced Models of the Effect of School Quality Measures on House Prices (From Gibbons, Machin and Silva, 2009)

	(1) OLS, all England	(2) OLS, boundary	(3) Cross-LA, boundary
Age 11-7 Value-added, (year t – t-4)	10.64	14.23	3.69
	(0.55)	(1.03)	(0.87)
Age7 English, maths (year t-4)	3.66	0.53	2.75
	(0.45)	(1.05)	(0.80)
Inverse property distance weights	No	No	Yes
Admissions authority boundary fixed effects	No	No	Yes
Distance to boundary cubic	No	No	Yes
Observations	1656001	138132	138132

Notes: Table reports regression coefficients and standard errors multiplied by 100 to give the % effect of a one point change in explanatory variables. Dependent variable: log house sales price. School characteristics imputed from schools accessible from housing transaction site. Control variables are: average rooms per dwelling in transaction's census 2001 output area, census output area proportion of households social renting, census ward population density, ward proportion under continuous or semi-continuous urban land cover, number of schools accessible from transaction site, average distance to accessible schools, distance from transaction site to local authority boundary, year dummies. Sample based on transaction pairs for second-hand home sales in years 2003, 2004, 2005 and first quarter of 2006, from Land Registry "Pricepaid" postcode dataset. Columns (1) and (2) include additional controls for property type (detached, semi-detached, terraced, flat/maisonette) and ownership type (leasehold or freehold). All variables in Columns (3) are differences between neighbouring transaction pairs on opposite sides of school admissions authority boundary, where neighbouring pairs are matched by transaction year, property type and ownership type. Standard errors are clustered on matched nearest sites across boundaries (15489 clusters, Columns (3)), or clustered on Census ward (Columns (1) and (2)). Test for equality of coefficients on age-7 tests and value-added in Column (3) model fails to reject null (p-value = 0.359).

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For more information please contact the Publications Unit
Tel: +44 (0)20 7955 7673; Fax: +44 (0)20 7955 7595; Email: cep.info@lse.ac.uk
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