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Housing Valuations of School Performance

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Abstract

In this Chapter, we critically review the sizable literature that values school quality and performance through housing valuations. While highly variable in terms of research quality, the literature consistently finds housing valuations to be significantly higher in places where measured school quality is higher. Thus parents are prepared to pay substantial amounts of money to get their children educated in better performing schools. This conclusion emerges from studies across many countries, using a variety of identification strategies, and at different levels of the education system.

Keywords: Housing Prices, School Quality, Hedonic Regressions

JEL Classifications: C21; I20, H75; R21.

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1. Introduction

For many years, economists have sought to understand how much, and along what dimensions, parents value better schools. This question has been approached in a number of ways, but the dominant research strategy uses housing market data to calculate how much more parents are willing to pay to live in an area that has a higher performing school. Given that residence often determines school attendance, the research attempts to compare prices of two houses that differ along only one dimension: one is associated with a better performing school than the other. The empirical challenge 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.

In this Chapter we discuss this line of research by critically appraising the now sizable literature on school quality and house prices. There are at least two main aims of this literature: first, to uncover how much parents are prepared to pay for the opportunity for their children to attend a better performing school and, second, to consider how school quality drives micro-geographic patterns of house prices. In our review, we begin by describing the standard hedonic valuation method that is now widely used in empirical research in this area, with a particular focus on how it facilitates estimation of housing premia for local amenities like better schools. We then discuss common data issues and related methodological difficulties that arise when estimating these premia. Finally, we consider the evidence, again focussing upon how methodological improvements and refinements have altered the way in which credible estimates have been obtained. We discuss this in the context of the large body of US and UK research, along with the smaller amount of evidence from elsewhere in the world, and we classify work according to the different

methodological approaches that are adopted. We conclude by offering a critical assessment of what we learn from this literature and highlight aspects where more research is required.

2. Using Housing Expenditures to Value School Quality

A long tradition of research in several branches of economics has used data on housing expenditures as a means of eliciting the prices of, or willingness to pay for, local amenities (see Sheppard, 1999). Usually this is motivated through the hedonic analysis of housing markets, whose theoretical underpinnings are described by Rosen (1974), and from which one can derive empirically implementable models that relate house prices to local amenities of interest. The approach, in various guises, has been widely used to study the demand for housing attributes and to value amenities like school quality, crime and environmental factors.

Studies that derive empirical specifications using hedonics range from regression-based property value models relating micro-house prices to local amenities in a reduced form setting, to the more technically complicated estimation of the structural demand and supply parameters of the Rosen model. We describe these different forms of modelling in this section, and make general comments on their success (or otherwise) in pinning down the empirical connection between housing values and school quality.

Theoretical background

To identify the house price premium associated with better school quality we need to consider the nature of empirical models that estimate how property characteristics and neighbourhood attributes affect housing prices in local markets. The most common approach that is applied either begins with, or in some way bases

itself upon, the Rosen (1974) analysis of the demand and supply of composite goods. The Rosen model describes a market equilibrium in which consumer choice over a composite good – like housing – amounts to choosing an optimum bundle of commodities – like house characteristics (e.g. house size) and local amenities (e.g. school quality).

In equilibrium the Rosen model, for given consumer preferences and income, sets the marginal benefit of improving any part of that bundle (e.g. finding a bigger house, or living in a location with a better quality school) equal to the utility costs of the additional expenditure involved. This provides a justification for using expenditure on a house to monetise the benefits of its observable attributes. Thus if it is possible to estimate how much housing expenditures change with marginal changes in one attribute (holding the others fixed), then this can be interpreted as the marginal willingness to pay for that attribute, or its 'implicit price'. The locus that traces out the relationship between housing expenditures and the quantities of its composite attributes has become known as the 'hedonic' price function.

A second key insight from the Rosen model is that buyers (like sellers) in this kind of market are heterogeneous in their preferences and income. This heterogeneity means that the price of any particular housing attribute is not unique even in a single housing market. For instance, the 'price' associated with an improvement in school quality may be low in areas of the market where school quality is generally bad, because buyers and sellers here place little value on school quality (e.g. if buyers do not have children). Conversely, the price of school quality in higher quality areas may be very high, because buyers in this area of the market are willing to pay heavily for marginal improvements in their children's academic achievements. In other words, the 'hedonic' price function can be highly non-linear, with implicit prices that vary

over the distribution of housing and neighbourhood characteristics. The slope and shape of this relationship is anchored by the relative number (or density) of consumers (buyers) and suppliers (sellers, property developers) in different parts of the market (Epple, 1987).

Other factors influencing the supply of attributes will also interact with characteristics in the hedonic price function, especially alternative sources of supply for the commodities embodied in housing location. For example, in our area of interest, it seems natural that the price of high quality private education should cap willingness to pay for state school quality via the housing market. Similarly, if there is a lot of choice and competition among good local schools, then housing prices might be unresponsive to inter-school differences in quality within the choice set. These are issues we will return to when we look at empirical evidence on the value of schooling.

If the hedonic price function is correctly estimated (i.e. obtaining the equilibrium relationship between housing expenditures and the component attributes of housing and its location), it is possible to calculate the implicit prices of each of these attributes. The implicit price can be calculated as the estimated derivative of housing expenditures with respect to attributes. It is important to ask what these estimated 'implicit prices' measure. If they are derived from a properly specified regression model, they can provide estimates of the *marginal* willingness to pay for changes in the corresponding housing attribute. However, for welfare analysis of non-marginal policy changes, one would want to estimate the underlying consumer demand functions (or the parameters of consumer utility functions), at least for a representative consumer, and possibly for different types of consumers in the market.

Estimation of these demand functions using estimated implicit prices is, however, often complex and difficult. Effectively, the problem is similar to the

standard identification problem of supply and demand equations in econometrics. That is, we can observe variation in quantities of attributes (embodied in housing) and variation in the corresponding implicit prices, but this variation reveals only the equilibrium relationship between price and quantity and not the underlying demand or supply equations. In the hedonic framework, there are multiple demand and supply equations in a single market at a given point in time, representing heterogeneous preferences of consumers and heterogeneous cost structures of suppliers.

Rosen's (1974) paper proposed a two stage approach to estimate these demand functions (or inverse demand functions), and there have been many subsequent attempts to implement it. In the first step hedonic equation, the implicit prices are estimated from a regression of housing expenditures on housing and neighbourhood attributes. In the second stage demand equation, the implicit price estimates are regressed on the observed attributes plus individual income and, on occasion, other buyer characteristics. However, since the implicit prices are simply calculated in the first stage as non-linear combinations of the observed attributes, this approach relies for identification on ad-hoc assumptions about functional form for the hedonic price function and demand function.[1]

Alternatively, identification of the second stage demand functions requires some source of variation in prices and quantities that is driven by supply shifts alone, and not by demand shifts, as in 'multiple markets' and instrumental variables approaches (Tauchen and Witte, 2001). Recent work by Ekeland, Heckman, and Nesheim (2002, 2004) has returned to the idea of using non-linearities in the hedonic price function to allow estimation of the demand functions. Their papers show that the hedonic price function is inherently non-linear, so the original idea of recovering the

[1] For instance, in a very simplistic setting for amenity x with a quadratic hedonic price function $m = \alpha_1 x + (\alpha_2/2)x^2$, then the implicit price of x is $p = \alpha_1 + \alpha_2 x$, and regression of p on x recovers the coefficient α_2.

implicit prices from the hedonic price function and running a regression of prices on a linear demand function is not as arbitrary as it may first seem.

However, before we even consider estimates of the demand functions, estimates of the implicit prices are required. This in itself is a major challenge due to basic omitted variables and simultaneity (endogeneity) problems that plague all non-experimental empirical research. In practice, the recent focus of most applied empirical work on micro housing models – particularly when considering local public goods, and neighbourhood and community attributes, like the quality of schooling – has shifted away from estimating demand function parameters. Instead, the focus tends to be more on the hedonic equation and estimation of the equilibrium implicit prices – that is, the equilibrium change in housing expenditure in response to changes in characteristics – using the tools used in other areas of empirical economics, particularly the research design approach that has become prevalent in labour economics (see Card, 2006).

This therefore forms the background for the empirical work considered in this Chapter. It should be acknowledged that the work valuing school quality through the housing market varies significantly in terms of the closeness of its connection to the Rosen model. This is reflected in the different methodological approaches using a range of reduced form and more structural estimations that exist in the literature. We aim to discuss the large body of evidence on estimating implicit prices that has been brought to bear on the question of how much parents will pay for access to higher quality schooling. In doing so, there are a number of data and modelling issues that commonly feature in empirical work in this area. We will carefully discuss these before reviewing and appraising the literature.

3. Data Issues Relating to House Prices and School Quality

There are a number of practical data issues and difficulties that commonly occur when estimating a willingness to pay from hedonic price equations. In the context of inferring the implicit price of school quality from house price equations, these include: use of housing valuations data; measurement of school quality; the mapping of housing and school level data; the institutions associated with school admissions and the definition of well specified catchment areas.

Housing Valuations

The idea of using land values to value "place" has a very long history (e.g. the foundation works of von Thunon, 1826, or Hurd, 1903, and the classic urban economics exposition of Alonso, 1964). The intuition that the value of a piece of land reveals something about the demand for the location of that land is straightforward. Less obvious is what we can learn when each place provides a large bundle of commodities of different types – related to the environment, schooling, labour market, accessibility etc. – and we are interested in the value consumers place on each of these commodities separately. Just to muddy the waters further, pure land values are rarely observed. Instead, the underlying value of place needs to be disentangled from the overall expenditure on whatever structure has been built on it.

This generates the need for statistical models that control for other confounding factors. In very general terms, this hedonic price function can be specified as relating the price (p in logs) of a house sale, 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, measured on the basis of school characteristics at periods prior to the house sale. One can think of these attributes 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. As discussed below, for valuing school quality, the matching of houses to schools is critical for this.

There are a number of pertinent observations about this empirical model. First and foremost, we want the estimated coefficient on school quality, β, to reflect the causal impact of school quality on house prices. As we have already stated, the aim of our survey is to critically appraise the ability of research to identify this parameter. While we will discuss empirical strategies for estimating this parameter in future sections, substantial measurement issues exist and we consider these next.

Measuring School Quality

Up to this point, we have been somewhat vague in our description of our measures of "school quality", $s(c)$. However, there is an extensive literature trying to determine what it is about schools that is important. One technique has been to examine which characteristics of a school are capitalized in housing prices.

If one looks at the standard education production function (see Hanushek, 2006, or Todd and Wolpin, 2003, for more extensive discussions), student performance is generally denoted as a function of a variety of inputs, including family characteristics, student ability, and school quality. In order to isolate the role of school quality, the production function can be estimated in first differences; as a result, the change in student performance is a function of the change in the school inputs, assuming other characteristics are unchanging over time and will therefore be differenced out. The value of a school can be thought of in a similar way; parents should pay for the additional learning that the school contributes. As a result, researchers have examined the role of value added in the hedonic housing price regressions.

Hayes and Taylor (1996) run a horserace to try to determine what it is about schools that parents value. Using data from the Dallas school district, they find that parents do not value changes in school expenditures but do in fact value changes in school test scores.[2] Dills (2004), using data on total housing values within Texas school districts, examines the effect of changes in house value associated with gains in test scores following the introduction of high stakes testing. She finds no effect of increasing passage rates of Texas Assessment of Academic Skills (TAAS) scores on housing values, suggesting either that parents do not respond to changes in school quality or the TAAS exam is a poor proxy for school quality. To test these competing hypotheses, she turns to other measures of student performance and examines the relationship between changes in SAT and ACT "passage rates" (defined as the percentage of graduates scoring above either 1000 on the SAT or 24 on the ACT) and changes in housing values. She finds that housing values do in fact respond, suggesting that value added, when perceived as true value added matters.

[2] Note that their data consists of 288 houses.

This finding has not been robust in the literature, however. Downes and Zabel (2002) use data from Chicago and conclude that parents value average test scores and not measures of value added. While they note that, theoretically, value added is what should matter, their evidence suggests the level is what does seem to matter to parents.

Brasington (1999) and Brasington and Haurin (2006), both test the value-added model. In Brasington (1999), the author estimates 444 hedonic housing estimations and compares 37 different measures of school quality and concludes that, while expenditures per pupil and student test scores do have a significant effect on housing prices, the measure of value added does not. In Brasington and Haurin (2006), the authors expand upon the earlier work by Brasington by using different measures of value added (relative to the urban area of each school district, not the state as in the previous paper) and use more test score data that enables them to follow a cohort of students over time. Again, they find little support for the value added model.

Much the same conclusion is reached in Gibbons, Machin and Silva's (2009) work on English primary schools. They consider both the level of test scores at the end of the primary school sequence and value added through the primary school years and conclude that parents value the level of test scores (which, incidentally, is the headline figure published in the English media). Considering other aspects of school quality does not affect this conclusion.[3] In related but separate work, Gibbons and Silva (2008) extend the range of possible valuation criteria to include measures of parent satisfaction with the school and (self-reported) child happiness. They find no relation between house prices and these subjective assessments, concluding that it is

[3] Expenditure per pupil, pupil-teacher ratio, number of full-time equivalent pupils and local housing taxes. Pupil characteristics include percentage of pupils eligible for free school meals, percentage of pupils from ethnic minority and percentage of pupils with special educational needs.

more concrete measures like test scores that parents value in choosing schools for their children to attend.

Matching of House Prices to Schools

A practical modelling concern for work in this area is that house prices and schools are not usually measured at the same level of (dis)aggregation. One then needs a means of matching house locations and school locations. The task is greatly simplified if there is a rigidly defined system of catchment areas or attendance zones, as is common in the U.S., since there then is a one-to-one mapping between residential location and school attended.

However, catchment area definitions - or indeed the very existence of catchment areas - differ considerably depending on the institutional setting. Figure 1 shows the rigid catchment zones in Paris in Fack and Grenet's (2010) study. In other places, like England (as in the work of Gibbons and Machin, 2003, 2006), proximity based attendance rules generate a much more fuzzy (often implicit) attendance zone which also depends on the demand for particular schools. In yet other places (like in Bogart and Cromwell's, 2000, study in Cleveland or Ries and Somerville's, 2004, study of Vancouver) catchment zones may vary over time and, on occasion, be redrawn entirely.

The differing nature of catchment areas adds an important set of modelling concerns that matter for identification of the school quality premium, β. Consider a situation where formal, rigid attendance boundaries do not exist (e.g. in the case of the England where proximity of residence to a school is the key factor determining school admission). We can, given appropriate data, easily ascertain which schools are located close to specific properties in a data set. But which schools are relevant? Given that many pupils do not attend their nearest school (Briggs et al 2001, Gibbons, Machin

and Silva 2008), there is ambiguity how to measure the characteristics of the "school" (or potential set of schools) associated with any particular house.

Without clearly defined catchment areas, considerable efforts need to be made to ensure that the link between residential location and accessible schools set up in the empirical analysis is a reasonable representation of the situation on the ground.

4. Empirical Methodologies and Review of Evidence

Our main focus is on the extent to which empirical investigations yield plausible estimates of the implicit prices of school quality attributes in housing models. In addition to the data and measurement issues mentioned previously, there are significant empirical challenges. Most notably, the full range of relevant housing characteristics and neighbourhood attributes are never observed by empirical researchers, so estimates are plagued by standard omitted variables and endogeneity problems. We next explain the methods that have been used in the recent literature to try to circumvent these problems.

Complications for Empirical Implementation: Sorting and Local Amenities

There are numerous scenarios under which estimation of the implicit price of local public goods, community related amenities and other spatial goods via property value models presents the researcher with significant challenges; here we will discuss the 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, 1998, 2003, or Bayer and McMillan, 2005) describes how voting on public school funding (and hence school quality) can be affected by the characteristics of the people

in the neighbourhood.[4] This introduces an endogeneity, or reverse causation, problem; the types of people who move to a neighborhood then influence the characteristics of the neighborhood and schools. An easy example is school spending; if higher house prices lead to higher property tax revenues, a high willingness to pay for school quality could lead to an increase in school spending (and hence quality) itself. Unfortunately, researchers are severely limited in their ability to model this endogeneity; as a result, much of the research takes a partial-equilibrium perspective, assuming that marginal house buyers are not going to have a significant effect on neighborhoods and school quality.[5]

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. The following sections focus on how researchers have attempted to deal with the correlation between neighbourhood characteristics (observed and unobserved) and schools we observe in the data.

Empirical Approaches and Evidence

We now move on to discuss the findings that emerge from the various different methodologies that have been used in the literature. We consider six of

[4] The seminal work is by Tiebout (1964) describes the sorting of individuals by preferences for public goods.

[5] Indeed, this issue becomes highly relevant in some contexts, for example in the US and other countries where local property taxes generate a direct link between housing values and school quality working through the level of public expenditure on schooling.

these, and classify papers by these groups[6]: regression based estimates; the use of parametric and non-parametric modelling of unobservable factors; instrumental variable approaches; discontinuity methods using administrative boundaries; differences, difference-in-differences, repeat sales and quasi-experimental methods; and papers that combine a number of these approaches. We consider each of these in turn:

i. Regression Based Estimates

The most basic way of dealing with the empirical challenges presented by hedonic housing price regressions, and the approach adopted in many of the earlier studies, is to use multiple regression techniques to control for as many observable house price determinants as possible; the assumption is then that whatever price variation is left is essentially random noise and hence uncorrelated with school quality. The earliest work on school quality valuation applied this approach by estimating a simple hedonic regression with the price as the dependent variable and house and school characteristics as the independent variables. In Kain and Quigley (1970), the authors regress house price or rental cost on structure characteristics (such as number bedrooms, bathrooms, etc), neighbourhood characteristics (such as median schooling of adults in census tract, racial composition of the neighbourhood, etc) and school characteristics (public school achievement.) They find only marginally significant effects of school quality (and crime) on house prices; however, they note that this may be due to the strong correlation between school characteristics and neighbourhood attributes.

Although Kain and Quigley do not find a robust effect of school quality on housing prices, since that time the literature has documented a significant relationship

[6] Some papers fall naturally into particular classifications, whereas others sometimes overlap. In the latter case, we classify according to what we view to be the dominant methodology adopted.

between the two. For example, Oates (1969), Sonstelie and Portney (1980) and Bradbury, Case, and Mayer (1995) all find a positive relationship between school spending and house prices, while Jud and Watts (1981), Fullerton and Rosen (1977) and Walden (1990) all document a positive relationship between student test scores and housing prices. The first panel of Table 1 gives details on the key findings from these and other similar regression based studies. Most studies uncover a sizable, statistically significant premium linked to school quality. However, more recent research has been quite critical of the strategies used in these 'condition on observables' regressions as they are heavily plagued by omitted variable bias and, hence, unreliable.

Given the wide range of housing characteristics, the basic multivariate regression approach often yields unwieldy 'kitchen-sink' regressions whose specification is governed largely by data availability. The decision as to which neighbourhood characteristics to include in such specifications remains largely ad-hoc; hence estimates are hard to interpret. Indeed, this traditional method is not an attractive way forward if we want credible amenity prices for policy purposes. More recent research in this field has adopted a number of empirical strategies to try to more rigorously address the problem of omitted variable bias. These strategies are based on isolating sources of variation in supply of school quality that are uncorrelated with other determinants of housing prices.

ii. Parametric and non-parametric modelling of unobservable factors

An alternative, complementary approach to the traditional regression-based methods of including a number of controls for observable housing and neighbourhood characteristics is to model part of the 'unobserved' spatial variation in prices (the g(c) function of equation (1)) directly using information on the geographical location of

house sales. For example, if there is an east-west downward trend in prices, and no observable demographic or physical characteristics explain this trend, then one could include the geographical coordinates of the house sales, just as one might include a time trend in a temporal model. More generally, house price models can include polynomials or elaborate parametric functions of x and y coordinates, or use "non-parametric" statistical methods to allow very flexible price surfaces in the x-y plane. The drawback in this method is that researcher must make some judgement about when to stop in eliminating 'nuisance' spatial variation, since the most flexible of specifications would eliminate the localised variation in prices and amenities that the researcher wishes to investigate.

There are a few papers in the literature that take this approach. They are summarised in the second panel of Table 1 and include work by Bogart and Cromwell (1997) and Cheshire and Sheppard (2004). Consistent with the earlier multivariate regression approach, these papers also report significant house price or rent premia connected to better school quality. Typically, however, their additional modelling of unobservables in the ways they attempt add only marginally to the regression based approaches in Panel I of the Table, and there are still likely to be biases associated with other unosbervables that can be controlled for using these methods.

iii. Instrumental Variables Approaches

One natural means to try and identify the causal effect of school quality on house prices would be to adopt an instrumental variables (IV) strategy, which would rely on finding variation in school quality that is otherwise unrelated to housing prices. While this approach has recently been relatively successful in some areas of the economics of education (for example, in estimating the earnings returns to education as discussed in Card, 1999), in the area of valuing school quality it has

proven hard to find credible instruments for school quality (or indeed other neighbourhood amenities), and studies rarely use this method alone. Indeed, in this light it is not surprising that the literature contains very few such studies - Panel 3 of Table 2 notes the papers by Bradbury, Case and Mayer (2001), Downes and Zabel (2002) and Rosenthal (2003). From the IV strategies adopted in this work, it seems hard to conclude anything other than the fact that this approach has not been especially successful in this area.[7]

iv. Discontinuity Methods Using Administrative Boundaries

By the early 1990s, researchers began to consider markedly different approaches for isolating the role of school quality from the role of neighbourhood characteristics. One confounding factor is the fact that the boundaries that determine school quality and those that determine the provision of other public goods are coterminous. In an effort to circumvent this problem, Bogart and Cromwell (1997) compare houses in different school districts but within the same political jurisdiction, so that non-schooling public services are the same in the houses being compared. From this, the authors argue they are able to derive the net-of-tax value of the distinct public services (schooling) in the two jurisdictions.

While clearly innovative, this paper suffers from a number of limitations. Most of the public school districts were coterminous with political jurisdictions, thereby providing little clean variation in school quality. Secondly, the coefficient on the school characteristics provides a net-of taxes marginal valuation; because both taxes and school quality varies, it is not clear that the coefficient provides the parameter the authors would ideally like to estimate.

[7] Some of the quasi-experimental approaches considered below under method v are clearly related to the search for exogenous variation in school quality that can be used to identify the causal impact on housing valuations.

Following on this idea was work by Black (1999); she uses what was later termed a "regression discontinuity" approach to distinguish the role of school quality on housing prices separate from neighbourhood attributes.[8] In her work, she is looking within school districts in the Boston metropolitan area at houses on the opposite sides of elementary school attendance district boundaries. By comparing houses within a very close proximity to each other but associated with different elementary schools, one can argue that the houses are in the same neighbourhood, so any difference in house price can be attributed to differences in school quality.

As expected if earlier estimates were plagued by omitted variable bias, when she estimates the hedonic regressions with boundary fixed effects (which takes out all fixed characteristics of houses in the same neighbourhood but on opposite sides of attendance district boundaries), the estimates of the effect of school test scores on housing prices go down dramatically from the more traditional specification regressing house prices on test scores with standard controls for house and neighbourhood characteristics. She finds that house prices go up by approximately 2.5% for a 5% change in test scores.

One of the key assumptions of this strategy is that, while school quality changes discontinuously at attendance district boundaries, other characteristics such as neighbourhoods change only smoothly. In the limit, you could look at observations epsilon distance from either side of the boundary and the only difference would be the school quality. To verify that this is the case, Black examines the characteristics of houses on opposite sides of attendance district boundaries and finds them to be similar. In addition, she reduces her range of comparison, first including all houses within 1/3 of a mile of the boundary, then 1/5 of a mile, and finally houses within .15

[8] See Imbens and Lemieux (2008) for discussion of the regression discontinuity approach.

of a mile of the attendance district boundary. The results are robust to these specifications.

However, if other characteristics such as neighbourhoods or house quality change discontinuously at the boundaries as well, the identification strategy no longer gives the marginal valuation of school quality. While Black (1999) showed that there appeared to be no differences in observable characteristics on opposite sides of boundaries, work by Kane, Riegg, and Staiger (2006) (listed in Table 1 under vi. combined methods) using data from North Carolina has suggested that there may be differences in neighbourhood and house characteristics on opposite sides of attendance district boundaries.

Exploiting discontinuities at catchment area or administrative boundaries has been a feature of other modern empirical work in the area. In very different settings like English primary schools (Gibbons and Machin, 2003, 2006; Gibbons, Machin and Silva, 2009), middle schools in Paris (Fack and Grenet, 2010) and Australian secondary schools (Davidoff and Leigh, 2008) estimates based on the boundary approach have uncovered significant house price premia and, strikingly, the magnitudes of the estimates are rather similar to the US work. A one standard deviation increase in school test scores seems to generate house price increases on the order of around 3 to 4 percent.

It is worth noting that the capitalization literature in general relies on the assumption that housing supply elasticity is close to zero; in urban areas, this may not seem unreasonable. Brasington (2002) argues that the boundary fixed effects methodology is particularly susceptible to violations of this assumption because of higher housing supply elasticities at the boundaries of urban areas. As a result, he argues we would expect to see weaker capitalization effects at the boundaries relative

to the center of an urban area. Using data from housing transactions in Ohio in 1991, he finds evidence that this is the case. While this is less likely to be a problem in a densely populated metropolitan area, it does highlight the importance of our assumptions about the elasticity of housing supply necessary for inference in these models.

v. Differences, difference-in-differences, repeat sales and quasi-experimental methods

All of the methods discussed so far have relied on cross-sectional variation for identification. Given additional information on changes in the level of local amenities over time, there is scope for examining how the prices of individual houses, or the prices of neighbourhood clusters of houses, respond to these changes. For example, another strategy is to compare housing prices before and after changes in school quality, thereby attributing the change in house prices to the change in school quality. Yet another is to take 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. In these approaches the $g(c)$ term in (1) is differenced out by looking at changes (or sometimes, differences-in-differences when a comparison group is also differenced).

There is a substantial literature that focuses solely on identifying the value of school quality by relating changes in house prices to changes in school quality. Work by Clapp and Ross (2004) and Clapp, Nanda, and Ross (2008) relate changes in house prices (two-year and ten-year, respectively) with changes in school performance and

racial composition of a neighbourhood.[9] By looking at changes, they are able to difference out fixed differences in neighbourhoods, housing quality, etc. They find that changing the demographic composition of the school does affect housing prices but mixed evidence on the role of test scores.

A limitation of this type of analysis, however, is that the changes in school quality may be coincident with unobserved changes in neighbourhood and, as a result, estimates of the relationship between school quality and housing prices will still be biased.[10] Another strategy is to use an arguably exogenous shock to school quality induced by change in education policy and see how this change is related to housing prices.

The literature has consistently shown that shocks to school quality induced by changes in education policy are capitalized in housing prices. A number of papers have looked at how changes in finance or expenditures affect housing values. Dee (2000) examines the effect of changing educational expenditures induced by school finance reforms on housing prices. Using data from California, Dee finds that new school resources were in fact capitalized in house prices, with the poorest school districts showing an increase of at least 8%.[11]

Cellini, Ferreira, and Rothstein (2008) examine the effect of school investment in structures induced by bond passage on housing prices. Because districts that invest in infrastructure may be different from other districts and because the decision to invest may be correlated with other changes in the district, the authors compare districts that passed measures by a small margin to those that did not pass by a small

[9] They use a simultaneous equations methodology to allow for endogeneity of the minority composition of the school.
[10] This type of analysis is particularly susceptible to measurement error. See Kane and Staiger (2002a, 2002b) and Chay et al (2005).
[11] He also notes that the resulting house price increases offset the positive effect of increasing education quality by making it more costly to live in these neighborhoods.

margin, arguing that crossing the threshold is essentially "random". When they make this comparison, they find that school performance increases six years after the bond issue but that housing prices increase substantially more, concluding that much of the value of school facilities comes from dimensions of school output that are not reflected in student test scores.

School district structure can also affect parental perception of available school quality and hence housing prices. Reback (2005) looks at how housing prices are affected by the introduction of a limited amount of school choice. Using the implementation of inter-district choice in Minnesota, he finds that residential properties appreciated in school districts where students were able to transfer out to preferred school districts, while housing values declined in districts that accepted transfer students.

So far, we have assumed that parents know the school quality and, from there, have tried to estimate their valuation. But is this really the case? Or can the provision of "information" create changes in the housing market? There is a separate literature on the role of information about schools on housing prices. In this case, there may be no actual change in school quality but a change in the perception of school quality.

Figlio and Lucas (2004) use repeated sales in Florida to examine how the housing market responds to information on school quality. The introduction of school report cards in 1999 led to changes in residential property values beyond the estimated effects of test scores and the other components of school grades. This is somewhat surprising given that most of the school grades are purely functions of test scores and other publicly available data, suggesting that there the publication of these school quality grades in fact provided new information to parents.

Work by Kane, Staiger, and Samms (2003) uses data from Mecklenburg County, North Carolina, to look at the effect of school quality information introduced by school report cards on housing prices. In 1997, 13 out of 61 public elementary schools were labelled as low performing based on proficiency in end-of-grade exams. Despite finding strong and significant effects of average school test scores over a number of years on housing prices (using the boundary fixed effect method used in Black 1999), the authors find no evidence of year to year fluctuations in school test scores having an effect on house price volatility.[12] This is in contrast to the findings of Figlio and Lucas; the authors suggest that the absence of a response reflect the fact that most of these schools had been poor performing for some time and there was therefore little new information in the report cards.

In the context of a loss of neighbourhood schools and school re-districting in Cleveland, Bogart and Cromwell (2000) adopt a quasi-experimental approach based upon the redrawing of catchment area boundaries. They study the case of Shaker Heights, Ohio, where the number of elementary schools was reduced from nine to six, and they find a significant loss in housing values when the realignment occurred.

Similarly, Ries and Somerville (2004) treat a redrawing of school catchment zones in Vancouver in January 2001 as an experiment that exogenously induces changes in school quality that in turn can affect housing valuations. This was a substantial rezoning that had a potential impact on around 1 in 5 Vancouver residences. Moreover, their analysis uses time series data to try and pin down the effects of the redrawing on housing values. The authors find significant effects of school quality on housing prices only for the most expensive quartile of residences, a

[12] Interestingly, their estimated effect of school test scores on housing prices is larger than that of Black (1999). They find that a one school-level standard deviation change in test scores is associated with a change in housing prices of 5 percentage points, over double the 2.2 percentage point difference found by Black.

finding they interpret as suggesting that these residences are purchased by high-income households who have strong preferences for good schools.

Finally, Machin and Salvanes (2010) consider an admissions policy reform in Oslo that generated a switch from zone based to open enrolment in the 1997/8 academic year. They exploit this change to estimate the house price premium associated with better school performance before and after the reform, hypothesizing that the value of being located in a higher school quality catchment area would decline with the introduction of school choice. They adopt a difference-in-difference type analysis (coupled with boundary discontinuities) and show that, while pre-reform there was a significant 2%-4% increase in prices for a one standard deviation increase in school average pupil marks, this fell significantly post-reform as school choice was opened up and children could cross the old boundaries to attend school.

vi. Combined Methods and Alternative Approaches

There are a small number of papers that combine a variety of the methods discussed above to try and pin down the causal impact of school quality on house prices. Kane, Riegg, and Staiger (2006) apply two different strategies to identify the relationship between school quality and housing prices; the first is the boundary discontinuity method and the second relates the change in housing prices associated with a change in school district boundaries resulting from court ordered desegregation. Using data from the Charlotte-Mecklenburg school system, the authors find that both methods result in a positive and statistically significant relationship between housing prices and school quality. Consistent with earlier work, these estimates are substantially smaller than naive OLS estimates.

Gibbons and Machin (2003, 2006) also use multiple methods in their valuation of English primary schools. They adopt several of the approaches we have considered

to date, including semi-parametric modelling of unobservable factors, discontinuities at school district boundaries, and instrumental variables using historically determined school characteristics as instruments. They interpret their results as bounding the school performance effect; estimates range from 3 percent to 6.7 percent higher house prices associated with a one standard deviation increase in school quality. The IV estimate of 6.7 percent is very much viewed as an upper bound, with smaller effects from the discontinuity approach.

A rather different approach using multiple methods, but underpinned by a more structural modelling technique, is adopted by Bayer, Ferreira, and McMillan (2007). They estimate a model of residential sorting that considers the value of schooling from a general equilibrium perspective.[13] They implement a two-stage structural approach that imposes a particular functional form on the residential choice and sorting process (coupled with an instrumentation strategy). In particular, the authors follow the approach of Berry et al. (1995) and first specify a functional form for the indirect utility function of a household with given set of characteristics and given housing choice. This depends linearly on the characteristics of the housing choice and of the surrounding neighbourhood, plus interactions between these attributes and household characteristics. They then estimate a multinomial logit model of actual housing choices to retrieve the set of parameters that characterise the mean indirect utility function of all households in a given housing choice and the household specific components. Finally, in the last step of their procedure, the authors use the estimated parameters to control for the effect of heterogeneous preferences in a standard hedonic price regression. The authors argue that, although the empirical work using boundary fixed effects methods give very small effects of school quality

[13] Bayer, McMillan, and Ruben (2004) estimate a model of residential sorting that is more general and not explicitly focused on school quality.

on housing prices (including their own estimates), when they consider the combined effect of housing prices and residential sorting, they find much larger effects of school quality. This highlights the importance of considering neighborhood sorting as well. While this approach does allow for general equilibrium effects, it is worth noting that 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.

Availability of Private Schooling

One final issue we need to consider is the fact that the literature focuses primarily on state-provided education. However, in most countries, private schooling alternatives are available. While 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), much less of the empirical work considers this in detail. Fack and Grenet (2010) is one exception where, in their analysis of Paris middle schools, they explicitly argue that the presence of private schools has a mitigating influence upon the house price-school quality association. 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

Estimating the extent to which parents are prepared to pay more for access to schools they perceive to be of higher quality has been a major preoccupation in the economics of education in the last thirty to forty years. As our review makes evident, almost all

of this work shows a significant statistical association between housing valuations and school quality. Indeed, much of the work reveals that parents, in a wide range of international contexts often with very different institutional features, are prepared to pay sizable sums of money for access to better performing schools.

One striking characteristic of the large body of work in this area has been the clear improvements and refinements of methodology over time. Traditional multivariate regression techniques have been replaced by regression discontinuity approaches, instrumental variables, and difference-in-differences approaches. This recent work can, in certain settings and under certain assumptions, identify the causal impact of school quality on housing valuations. Moreover, there is something of a consensus in this literature that school quality matters and significantly raises capitalised housing values. In our view a not unreasonable benchmark summary of the magnitude of the average causal impact is that a one standard deviation increase in test scores raises house prices by around 3 percent.

However, many research challenges remain. As better data becomes available, researchers can focus more on what features of a school make a "good" school as perceived by parents; this will be a good complement to the decidedly inconclusive literature on the role of school inputs on student outcomes. In addition, with access to more detailed data on the characteristics of homebuyers that registry data could provide, future work can help better understand the sorting process involved in household location decisions.

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Figure 1:
An Example of Catchment Areas, Paris School Year 2003-4

Table 1:
Summary of Research Findings, Organised by Methodological Approach

Study	Setting	Data	Impact of School Quality	Comments
i. Regression Based Estimates				
Oates (1969)	US – New Jersey	Residential communities within 53 municipalities Census (1960). Expenditure per pupil.	Increase in spending per pupil from $350 to $450 per annum increases house prices by $1,200 (1969 prices).	
Kain and Quigley (1970)	US – St Louis	Survey of 1,500 households (1969). Average eighth grade math score.	1SD in school quality increase rent by $2.63- $5.05 per month	Very detailed information on housing quality. Basic hedonic modelling.
Grether and Mieszkowski (1974)	US – New Haven	830 sales of single family homes (1962-1969). Reading percentiles for elementary schools from New Haven.	Moving from school district in 50th pctile to 90th pctile increase house value by 9% ($2000). PTR from 25 to 30 lowers price by 4.5% ($1000).	
Fullerton and Rosen (1977)	US – New Jersey	Residential communities within 53 municipalities Census (1960/1970). Expenditure per pupil. Average reading /math scores 4th grade.	Increased reading and math score raises prices by 0.5 and 0.27 respectively. (No scale given). Being in top decile relative to bottom increases price by $4,300 (1970 prices).	Expenditure per pupil has no effect on house prices.
Brueckner (1979)	US – New Jersey	53 municipalities Census (1960), Twenty-Third Annual Report of the Division of Local Government, State of New Jersey.	No effect of educational expenditure on house valuations.	
Sonstelie and Portney (1980)	US - San Mateo County, California	Gross rent in single family dwellings (1969-1970). Elementary expenditure per pupil, average reading improvement from 1st to 3rd grade by school district.	Annual gross rent of a median house is increased by $52 for each additional month of average reading improvement. $1 increase in pupil expenditure increases gross rent of an 8 room house by $1.50.	The effect of expenditure per pupil increases with the number of bedrooms.
Jud and Watts (1981)	US – Charlotte, North Carolina	Sales records from single family residential property (1977). School level average of 3rd grade performance on state reading test.	Increasing in performance by one grade level raises housing values by 5.2%.	
Atkinson and Crocker (1987)	US - Chicago	1,283 insurance valuations of detached single family residencies (1967-67). Elementary school reading and maths scores, district means.	No effect.	
Walden (1990)	US – Wake County, North Carloina	598 house sales in Wake County, North Carolina (1987). Use elementary and middle school California	Elementary and SAT scores not significantly related. 1% point increase in Middle schools scores increases house	Districts with magnet schools offer more school choice to parents and have less capitalisation.

		Achievement Test scores and SAT scores.	price by 0.2%. Reading had a larger effect than math.	
Brasington and Haurin (1996)	US – Ohio, 6 largest metropolitan regions	45,236 real-estate transactions (1991) % of fourth-grade students in each district who pass the reading proficiency test (1996).	2SD increases in school quality increases house prices by 18%.	Capitalization of school quality differences occurs on a per lot basis rather than per square foot of land.
Case and Mayer (1996)	US – Eastern Massachusetts	135,000 pairs of retail transactions (1981 - 1994). Spending per pupil.	High quality school districts appreciate in value slower than low quality districts.	
Hayes and Taylor (1996)	US – Dallas, Northern and Southern	288 single family homes sold in July 1987. Non school data from 1990 Census of Housing and Population. Sixth-grade mathematics achievement.	1% increase in math scores increases house prices by 0.26% in northern Dallas.	No effect of pupil expenditure on house prices.
Brasington (1999)	US – Ohio, 6 largest metropolitan regions	27,440 real-estate transactions (1991) % of fourth-grade students in each district who pass the reading proficiency test (1996).	No conclusive results, 3 significant positive, 2 significant negative. 1% increase in pass rate, increases log prices by 1%.	Investigates other school quality measures, including, spending, PTR, teacher pay and value added.
Cheshire and Sheppard (1998)	UK – Reading and Darlington	840 real-estate transactions (1984). Catchment area dummies.	Residences in a the catchment area of a 'Premium school' cost an extra 8% in Reading and 12% in Darlington.	
Clark and Herrin (2000)	US - Fresno County, California	6837 residences from property tax data (1990-1994). SATs, dropout rate, PTR.	1SD increase in taking the SAT raises 3.1%. An extra teacher per 100 students district-wide, increases housing prices by 16% (gross).	
Barrow (2002)	US - District of Columbia	12,805 residences. High school mean SAT scores.	White households with children in the top income quintile are willing to pay $3,300 for schools that generate a 100 SAT point advantage. No effect on black households.	Accounting for unobserved neighbourhood factors by controlling for children present in household.
Brasington (2003)	US – Ohio, 6 largest metropolitan regions	9509 houses real-estate transactions in 34 urban areas (1991) % of fourth-grade students in each district who pass 9th grade proficiency test on first attempt (1990).	1% increase in pass rate increases house prices by 0.01%.	The supply elasticity, 0.14, suggests nearly perfectly inelastic. Area residents require a large increase in price to induce them to supply an additional unit of public school quality.
Chiodo, Hernandez-Murillo and Owyang (2003)	US - Tucson, Arizona	9462 residential sales (1998-2003). School district dummies.	30-47% House price premium for houses in high value districts.	
Dills (2004)	US - Texas	Total taxable value of single family residential property within school districts (1994-	TAAS pass rates have no effect on house values. 1SD increase in pass rates on the ACT/SAT	Parents only care about the passage rate of certain tests.

		1999). Passage rates of Texas Assessment of Academic Skills (TAAS) and SAT/ACT.	Increases total house value by $2.8 million dollars (1.5% of the average total change over this period).	
Brasington and Haurin (2006a)	US – Ohio, 7 urban areas	77,578 real-estate transactions over 310 school districts (2000). % of 4th and 9th grade students in each district 4 proficiency tests on first attempt.	1SD increase in school quality increases house prices by 7.1%, using average tests scores. No relation to value added test scores.	OLS combined with spatial autoregressive model.
Brasington and Haurin (2006b)	US – Ohio	40,116 real-estate transactions urban areas (1991) % of fourth-grade students in each district who pass all 9th grade proficiency tests on first attempt (1990).	Price elasticity of demand for school quality -0.56 to -0.53. Income elasticity of demand 0.5.	
Chin and Foong (2006)	Singapore	13,790 real estate transactions (1999-2003) Average primary and secondary school performance.	Access and prestige of primary schools appeared to be a more important consideration when making a home purchase than that of secondary schools.	
Crone (2006)	US - Montgomery County, Pennsylvania	3150 home sales remaining in the 21 school districts Sales prices and previous sales price from property tax receipts (1998-1999). District and school level maths and reading tests for 5th and 11th grades.	1SD increase in school quality increase house prices by 1.7%-2.4%.	District levels scores more significant than school level scores. *intra-district* differences scores are not a significant determinant of house prices when controlling for district-wide averages.
Gravel, Michelangeli and Trannoy (2006)	France - Val d'Oise	8200 housing units, over 33 cities in Val d'Oise (1985-1993). Number of pupils repeating a grade and pupil teacher ratio.	1SD in school quality increase prices by 1.26% (1417 euros) Reducing class size by 1 increases value by 854 euros.	

II. Parametric and Non-Parametric Modelling of Unobservable Factors

Bogart and Cromwell (1997)	US - Cleveland Ohio	All arms-length sales of one-family owner-occupied houses in the three statistical planning areas, 11,000 (1976-1994).	High value school district is worth about $36 per month extra in rent.	Oaxaca decomposition of differences in average house prices across school jurisdictions into a component based on differences in observables and unobservable residual components.
Cheshire and Sheppard (2004)	UK - Reading	490 real-estate transactions (1999-2000). Primary School, proportion reaching target grade in maths science and	Primary schools: 9.8% for one standard deviation Secondary schools: 4.0% for one standard deviation (own linear	Model spatial distance parameters.

		English. Secondary School proportion achieving 5+ GCSE's A-C.	interpolation from authors reported results).	
Brasington and Hite (2008)	US – Ohio, 7 urban areas	Survey of 1606 homebuyer characteristics, 127,050 housing sales from 58 counties in Ohio (2000).	Mean elasticity of house price with respect to school quality is 0.19.	Uses mixed models.
Derrick, Sedgley and Williams (2008)	US - Howard County, Maryland	3164 homes sold (2002). School mean pass rate of 6 subjects grades 3rd 5th and 8th, SAT scores.	House price elasticises: 3rd grade insignificant; 8th grade 0.16-0.22; SAT scores 0.12-0.3.	Spatial autocorrelation.
III. Instrumental Variables Approaches				
Bradbury, Case and Mayer (2001)	US - Massachusetts	Use repeat sales house price information of 135,000properties (1990-1995). Per pupil expenditure and combined math and reading MEAP test score for 8th graders in 1990.	1SD increase in school spending (8.6%) increases house prices by 2%. Test scores have small but significant effect. Non-school spending have insignificant effects.	Instrument include 1980; property tax rate, % non residential property, per capita income.
Downes and Zabel (2002)	US - Chicago	American Housing Survey(1987-1991). Average district/school eighth grade reading component. Ownership information.	1SD in school quality increases prices by 14%.	Home owners pay more attention to test scores than per-pupil expenditures, or value added test scores.
Rosenthal (2003)	England	350,000 real-estate transactions (1995-1998). Inspections of 3000 secondary schools and proportion achieving 5+ GCSE's A-C.	1SD in school quality increases house prices by 2%. Elasticity of purchase price to school quality of 5%.	Instrument: Random timing of OFSTED school inspections.
IV. Discontinuity Methods Using Administrative Boundaries				
Black (1999)	US – Boston Massachusetts	All 22,679 real-estate transactions (1993-1995). Elementary reading and math scores.	1SD in school quality (5%) increases prices by 2.5%.	Cross-sectional study using attendance boundary discontinuities.
Weimer and Wolkoff (2001)	US – Monroe County, New York	1,193 real estate transactions (1997). Elementary schools, average ELA test score.	Elasticity of city housing values with respect to average test score ranges from 0.6 to 4.7.	Effect of: Student body composition, test scores, student-teacher ratios. Use catchment areas where they do not coincide with boundaries for other public goods, with fixed effects.
Leech and Campos (2003)	UK - Coventry	Advertised prices from one issue of local property guide (13/7/2000). Catchment area dummies.	20% premium for two popular schools, and 16% for a third.	Use of catchment area dummies, with increased prices in oversubscribed school areas.

Davidoff and Leigh (2008)	Australia - Australian Capital Territory	580 transactions, excluding apartments (2003-2005) Secondary school's median University Admissions Index (UAI).	1SD in school quality (5% in test scores) increases house prices by 3.5%.	Compare homes on either side of boundaries (600m).
Fiva and Kirkeboen (2008)	Norway - Oslo	79,322 real estate transactions (2003-2006). Lower Secondary School, adjusted grade point average (1 internal, 2 external).	1SD in school quality increases prices by 1.5%.	Exploit publication of school quality indicators on house prices. Grade point average adjusted for parental characteristics.
Fack and Grenet (2010)	France - Paris	Real estate transactions (1997-2003). Middle school maths, geography, history and French scores.	1SD in school quality increases prices by 2%.	Compare sales across school boundaries. Offering an outside option to parents, attenuates the capitalization of public school quality in the price of real estate.

V. Differences, Difference-in-Differences, Repeat Sales and Quasi-Experimental Methods

Bogart and Cromwell (2000)	US - Shaker Heights, Cleveland, Ohio	All arms-length sales of one-family owner-occupied houses in the three statistical planning areas, 11,000 (1983-1994).	Loss of high value school reduces house price by 9.9% ($5,738 – 2000 prices).	Redistricting of high quality neighbourhood school.
Dee (2000)	US - California	School district level data (10,000) from National Center for Education Statistics School District Data Book and housing values from 1990 census.	Court reform positively effected house prices. The poorest school districts found increases of 8%.	Changing educational expenditure due to court judgement.
Brunner, Murdoch and Thayer (2002)	US - Los Angeles	94,223 transactions of owner occupied single family homes (1975, 1980, 1985, 1990). District level average of 6th grade math and verbal scores.	1 point increase in performance increases price of homes by $300. $1 increase in spending per pupil increases price of homes by $6.	
Kane, Staiger and Samms (2003)	US - Mecklenburg County, North Carolina	86,865 sales for 67,066 single family homes with stable elementary school assignments between 1993-2001.	1SD (school level) increase in scores increases house prices by 4-5%. 1SD (student level) increased average house prices by 18-25%.	No evidence of volatility in housing prices to match the annual volatility in test scores.
Clapp and Ross (2004)	US - Connecticut	100,000 housing transactions (1995-2000). Eighth grade district mathematics score.	Math scores have no effect on house prices.	Simultaneous equations model, using price levels, school performance, and the racial and ethnic composition.
Figlio and Lucas (2004)	US - Florida	73,782 properties in 481 elementary school zones (1999-2001) Elementary school grades based on	10% premium for schools receiving an "A" grade in each year	Repeat property sales within small neighbourhoods in

		government evaluation.		Florida.
Ries and Somerville (2004)	Canada - Vancover	87381 repeat sales from 1996 to 2003 matched to information on 18 secondary and 69 elementary schools.	Cross section hedonics show strong school quality impacts, but once price trends are controlled for the only significant effects occur for the top quartile residences.	Rezoning that causes redrawing of catchment areas in January 2001 which took effect for school attendance in September 2001.
Reback (2005)	US - Minnesota	272 district-level residential property values (1989–1990 and 1997–1998). Index based on 7 test score measures over four school years. Elementary, middle secondary schools.	1SD in school quality increases prices by 3.8 to 7.7%	Identify the capitalization effects associated with the diminished importance of school district boundaries.
Cellini, Ferreira and Rothstein (2008)	US - California	Real-estate transactions (1988-2005) averaged at census block. 3rd Grade reading and math CAT, Stanford9.	An increase of $1 in educational spending increase house prices by $1.50. The total effect of spending on test scores would produce a housing price increase just over one percent.	Regression discontinuity on vote on education spending.
Clapp, Nanda and Ross (2008)	US - Connecticut	356,829 real-estate transactions (1994-2004), 8th Grade maths scores and demographic characteristics.	1SD in school quality increases prices by 1.3-1.4%.	Proportions Black and Hispanic more important when looking at long run changes.
Caetano (2009)	US – New Jersey	Restricted access 2000 U.S. Decennial Census data on 1 in7 households in 200 New Jersey educational districts. Information on house composition, rental price and sales price.	A 5% increase in test scores increase rental prices per child by 2.7% for high school pupils, 1.6% for middle school pupils and 1.4% elementary school pupils.	
Machin and Salvanes (2010)	Norway - Oslo	15,495 real estate transactions (1995-2002). Secondary school maths, Norwegian and English scores. Socio-economic characteristic of home buyers.	1SD in school quality increases prices by 2-9% with catchment areas, and 2-6% without.	Exploit admissions reform, removing catchment areas.
VI. Combined Methods				
Des Rosiers, Lagan and Theriault (2001)	Canada - Quebec Urban Community	4300 transacted single-detached, owner-occupied housing units (1990-1).	Sales price decrease by CAN$2685 per km.	Investigates the non-monotonicity of both the price–distance and price–size relationships with respect to primary schools
Gibbons and Machin (2003)	England	Average transaction price in 7444 postcodes, by property type (1996-1999). Proportion reaching target grade in primary school maths,	1 SD in school quality increases prices by 4% - 9% (3.3-6.9% for 10 percentage point increase).	Semi-parametric modelling of unobservable factors, discontinuities at school district boundaries, and

		science and English tests.		instrumental variables.
Gibbons and Machin (2006)	UK – Greater London	All real-estate transactions involving a mortgage (1997-2002). Proportion reaching target grade in primary school maths, science and English tests.	1SD in school quality increases prices by 3.8%	Multiple methods used (IV, cross-boiundary) with focus places on testing models where house price premia differ with distance to school.
Kane, Riegg and Staiger (2006)	US - Mecklenburg County North Carolina	89,793 properties (1994-2001) Maths and reading scores in elementary schools.	1SD in school quality increases prices by 10%.	Use differences in housing prices along boundaries and changes following the change in school assignments.
Bayer, Ferreira, and McMillan (2007)	US – San Francisco Bay Area (6 Counties)	Prices back engineered from 244,000 households tax forms (1978). Mean test scores by school over 2 years.	5% increase in school performance leads to 1% increase in prices.	Structural two stage approach based upon residential sorting, discontinuities at school district boundaries, and instrumental variables.