School Quality and Residential Property Values: A Review of Recent Developments and Applications

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Abstract

The measurement of consumers' marginal willingness to pay for public education provides a basis for evaluating and improving existing education policies. This study reviews recent empirical studies that examined the relationship between school quality and housing prices based on a hedonic approach. We classify the existing empirical works according to their identification strategies, discuss the magnitudes of the estimated marginal willingness to pay for public education, and highlight several key aspects that need to be investigated in future research.

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JEL Classification: C21; I21, H75; R23

I. Introduction

A large body of literature has been accumulated on the measurement of marginal willingness to pay (MWTP) for non-market goods, such as environmental quality and neighborhood amenities, coupled with its policy implications. Many previous studies use a hedonic approach to measure the MWTP for non-market goods, under the assumption that the value of these non-market goods is capitalized into local housing prices.

Given that residential location choice often coincides with school choice, evaluating parent's willingness to pay for school quality through housing valuations has been one of the most extensively investigated topics in the literature. An obvious empirical challenge is that there are often a number of housing and neighborhood unobservables that correlates both with housing values and with school quality. As a result, a number of alternative methods have been proposed to pin down the causal relationship between house prices and school quality. Comparing estimates based on different methodology allows us to understand potential biases and their underlying mechanisms in the hedonic applications. In addition, comparing results from different countries and/or institutional backgrounds can provide important insights in terms of the generalizability of empirical findings (i.e., external validity).

Several comprehensive literature surveys have already been published in the last decade (Black and Machin, 2011; Machin, 2011; Nguyen-Hoang and Yinger, 2011). The purpose of this paper is therefore to review more recent studies and to discuss improvements and re-

finements of methodology over time.

The structure of this paper is as follows. The next section introduces the basic framework of the hedonic approach and presents the major empirical issues. Section III presents an empirical framework for several important existing studies, focusing particularly on biases resulting from inadequate control of the neighborhood unobservables. Section IV overviews recent research trends from three perspectives: identification strategies on empirical analysis, magnitude of MWTP estimates, and several key topics in the literature. Section V discusses the advantages and disadvantages of using Japanese data, drawing on several previous studies. Section VI concludes.

II. Hedonic Approach

II-1. Basic Framework

Evaluating the value of non-market, neighborhood amenity has been an important topic in urban and environmental economics. Under the assumption that the value of neighborhood amenity is capitalized into local house prices, many previous studies have applied hedonic methods in order to evaluate the MWTP for neighborhood amenity (Rosen, 1974).[1] In our case, house prices can be higher in the neighborhood of a good public school, reflecting consumers' willingness to pay for good schools.

In the framework of the hedonic approach, individual houses represent not only a bundle of structural characteristics, such as size and age, but also a set of location-specific characteristics. These latter characteristics include, among others, accessibility, neighborhood housing and demographic composition, and local public goods such as schools. Let s be the quality of local public school and all other structural and location-specific characteristics be $\mathbf{z} = (z_1, z_2, \ldots, z_A)$. Thus, individual houses are characterized by the bundle of characteristics $(s, \mathbf{z})$.

Consumers are assumed to derive utility from a bundle of housing characteristics $(s, \mathbf{z})$ and numeraire goods consumption (x). They have utility function $U(x, s, \mathbf{z}; \xi)$ where ξ is a parameter representing the consumer's heterogeneity. The consumer's budget constraint is given by $y = x + P(s, \mathbf{z})$ where y is income and $P(s, \mathbf{z})$ is an equilibrium hedonic price function, i.e., housing value given its characteristics. The first-order condition describing the consumer's hedonic demand yields

$$P_s(s, \mathbf{z}) = \frac{U_s(y - P(s, \mathbf{z}), s, \mathbf{z}; \xi)}{U_x(y - P(s, \mathbf{z}), s, \mathbf{z}; \xi)}. \tag{1}$$

The left-hand side of the equation is the implicit price of school quality, i.e., the marginal

[1] In this paper, we focus mostly on the identification of "marginal" willingness to pay for school quality. Evaluating the welfare impact of "non-marginal" changes in school quality often requires more structural approach such as Rosen's classic two-stage procedure. Empirical issues and the recent development on identifying the non-marginal impact of location-specific characteristics can be found, for example, in Ekeland et al. (2004), Bajari and Benkard (2005), and Heckman et al. (2010).

impact of school quality on house prices, which can in principle be estimated from the observed data. The right-hand side is the consumer's MWTP for school quality. Equation (1) therefore provides theoretical rationale for identifying the consumer's evaluation of school quality through housing valuation.

II-2. Empirical Issues

Suppose we can observe price p, school quality s and structural and location-specific characteristics $\mathbf{z}$ for houses $i \in \{1, 2, \ldots, N\}$. A standard hedonic price function is given as

$$\log p_i = \beta s_i + \mathbf{z}_i'\boldsymbol{\gamma} + \varepsilon_i \tag{2}$$

where ε denotes an error term. As discussed in the previous section, the estimated coefficient β can be interpreted as MWTP for school quality. In the following, we will discuss major empirical issues in estimating hedonic price function given in equation (2). These include (1) measurement of the school quality s, and (2) omitted-variable bias due to unobserved neighborhood characteristics.[2]

II-2-1. Measuring School Quality

In equation (2), s_i represents the quality of educational services available for household i. In practice, however, an appropriate measure of school "quality" is not necessarily obvious. Since education is a multifaceted good, there are a number of potential aspects that constitute the quality of public schools.

To address this issue, several recent studies look at the household's school choice and examine how parents evaluate various school characteristics such as facilities, convenience or peer composition. For example, Burgass et al. (2015), using survey data on school choice in the UK, examine the school characteristics that influence the choice between public elementary schools. Their empirical results suggest that parents have strong preference for schools' academic performance (i.e., average scores on a standardized academic exam) and that more advantaged parents tend to value more on academic performance.[3] More recently, Abdulkadiroglu et al. (2020) use school choice data in New York City and examine whether observed school choice is influenced by academic performance of the existing students (i.e., average test score) or by its value added (i.e., test score improvement). Their empirical results show that, conditional on the average academic performance, schools' value added does not have any additional influence on school choice. These empirical results imply that parents and families tend to value peer quality rather than school effectiveness.

Schools' academic performance, either in its average or the value added, is a measure of school quality in terms of educational outcomes. Parents may also care about educational inputs such as schools' facilities or teacher quality as a means of improving educational out-

[2] In addition to the issues addressed here, the estimation of the hedonic price function involves a variety of empirical issues, including the choice of functional forms, spatial segmentation of housing submarkets, and various sample selection issues. For a broader discussion of the estimation of hedonic price functions, see Sheppard (1999) for example.

[3] Their results suggest that parents also value schools' accessibility and socio-demographic composition.

comes. There is also an extensive literature on the education production function that investigates the determinants of educational outcomes. Previous studies examined the role of school resources, including student/teacher ratio, teachers' education and years of experience, educational expenditures per student, school facilities (Hanushek, 2006; Todd and Wolpin, 2003). Estimating the education production function per se has a number of data and empirical issues and the causal impacts of various school resources on student's outcomes are still widely discussed in the literature. Despite the lack of empirical consensus on its impact on educational outcomes, school resources can still be one of the potential measures of school quality.

Previous studies on school choice and education production function suggest that school quality in equation (2) can be measured by schools' academic achievement (such as standardized test scores) and/or by their educational resources (such as teacher quality). So far, however, much of the previous research in the hedonic literature has primarily used average test scores as a measure of school quality. This is perhaps due to the lack of readily available data for student's academic value added or for detailed measures of school resources. Empirical results using value-added measures or school resources will be discussed later in Section IV.

Another empirical issue on the measurement of school quality relates to the spatial correspondence between residential location and available schools. Without open enrollment or school choice programs, residential location choice often coincides with the choice of a specific school to be enrolled in, through attendance zoning or school boundary maps. In this case, spatial mapping between housing and schools will not be a problem. In some countries or regions, however, attendance zones are not always strictly enforced or such geographic attendance rules are nonexistent. In such a case, one has to care about parental school choice problems on top of residential location choice, which substantially complicates the standard hedonic analysis.

While institutional factors such as open enrollment or school choice programs can create difficulties in measuring school quality, they can also be an advantage in the empirical analysis since the introduction of these programs provides exogenous variation in school quality at each location. Additional discussion of these issues will be provided in Section IV.

II-2-2. Endogeneity Issues

In recent empirical studies using observational data, quasi-experimental designs for the identification of causal relationships have become more important than before. This trend is also true with respect to empirical analysis based on hedonic approaches, and much of the recent research has developed in a way that incorporates a wide variety of quasi-experimental designs for causal inference (Parmeter and Pope, 2013; Ushijima, 2016).

In this context, a key concern in estimating equation (2) is the endogeneity of school quality and its possible correlation with the unobserved omitted neighborhood characteristics. In the presence of endogeneity, i.e., $E[\varepsilon|s, \mathbf{z}] \neq 0$, estimating equation (2) by the standard technique such as OLS will yield biased estimates and spurious findings. This will hap-

pen in a number of settings. First, higher housing prices can improve school quality (i.e., reverse causation). This can be particularly problematic in the public school system in the U.S., where school budgets are partly financed by local property taxes. The most recent figures suggest that approximately 33.6% of U.S. education spending on public elementary and secondary schools is funded by school district's property tax revenues.[4]

In this case, 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. Since the U.S. school system leaves much of school operation, such as teacher and staff personnel and school facility maintenance, to the discretion of school districts, increases in education budgets can directly result in improvements in school resources, and hence quality. Therefore, a reverse causation between house prices and school quality will create difficulties in the analysis based on equation (2). Unfortunately, however, much of the previous studies are unable to deal with this reverse causation issue and assume that marginal home buyers do not substantially change neighborhood characteristics and school quality (Black and Machin, 2011).[5]

Second, school quality can be strongly correlated with neighborhood characteristics due to residential sorting. If there are some unobserved characteristics correlated with school quality, a simple regression analysis based on equation (2) will provide a biased estimate of β. This omitted variables problem is widely recognized in the literature and several methods have been proposed. This point will be discussed in more detail in the next section.

III. Boundary Discontinuity Design

As discussed in the previous section, unobserved neighborhood characteristics can yield biased estimates of the impact of school quality on house prices. In the following, we look at several analytical methods proposed in existing research to address this issue.

Equation (2) assumes a situation in which variables that could affect house prices are fully observed by the econometrician. However, there are a myriad of structural and location-specific characteristics that can influence house prices, and the econometrician can almost always observe an incomplete set of these characteristics. Suppose that a subset $\tilde{\mathbf{z}} = \{z_1, \ldots, z_{\tilde{A}}\}$ of the housing characteristics $\mathbf{z}$ can be observed by the econometrician ($\tilde{A} < A$). In this case, the regression equation that can actually be estimated is

$$\log p_i = \beta s_i + \tilde{\mathbf{z}}_i' \tilde{\boldsymbol{\gamma}} + \tilde{\varepsilon}_i \tag{3}$$

where $\tilde{\varepsilon}$ is an error term that includes housing characteristics that are unobservable to the econometrician ($z_{\tilde{A}+1}, \ldots, z_A$).

[4] A breakdown by source of funds in FY 2015 shows that 55.2% of the total spending came from the federal or state government and 44.8% from smaller governmental units than the state, including school districts. A further breakdown of the latter shows that 81.3% came from property tax revenues, 14.9% from other public revenues, and 3.8% from donations and other revenues (Digest of Education Statistics 2018).

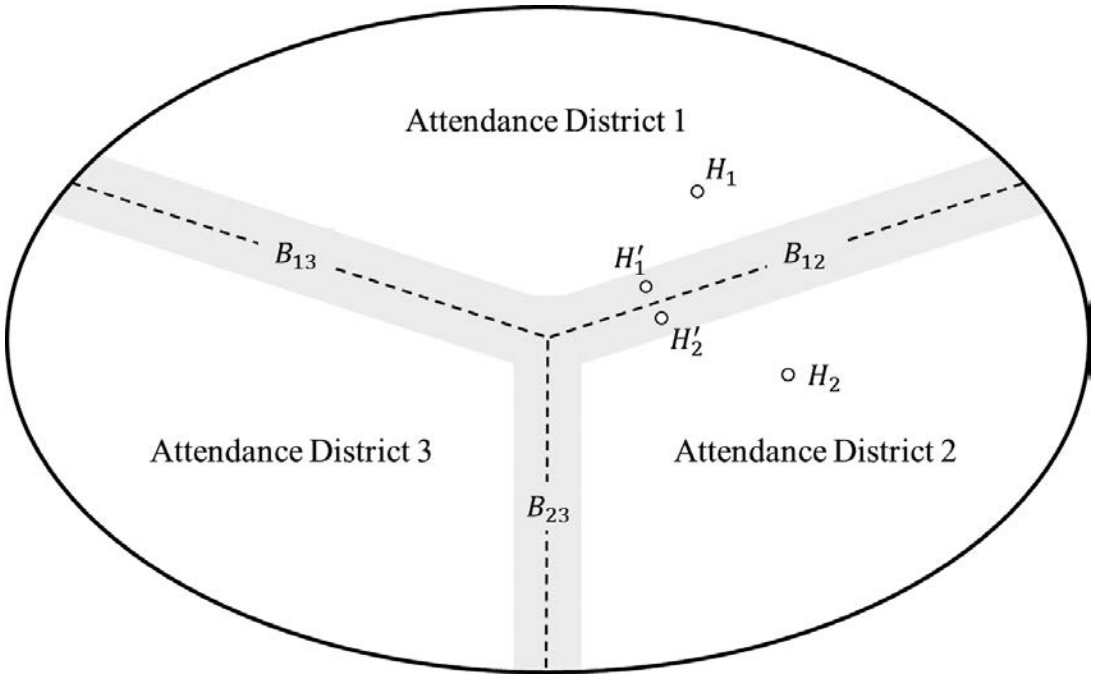
[5] Some studies have addressed this issue using the instrumental variables method. For example, Downes and Zabel (2002) use the percentage of rental housing and school-age children in the local population as IV and estimate hedonic regression similar to equation (2). The validity of these IVs, however, remains controversial.

The bias due to the omitted neighborhood characteristics arises because the error term $\tilde{\varepsilon}$ in equation (3) is correlated with school quality s (after conditioning $\tilde{\mathbf{z}}$). For example, neighborhood characteristics such as landscape is difficult to quantify and may be associated with school quality.

To circumvent the problem from omitted neighborhood characteristics, Black (1999) compares houses within a close proximity to each other but located on the opposite sides of school attendance zone boundaries. The basic idea of this method is as follows. Figure 1 shows three attendance zones within the same school district. Consider two houses, H_1 and H_2, located in different attendance zones. Since two houses are located in different school districts, the price difference is at least partly due to differences in school quality. However, the two houses are also likely to have different neighborhood environments as they are located far apart. If these neighborhood environments are not fully observable, and if unobservable elements of the neighborhood environment are correlated with school quality, then the observed price differences will reflect not only differences in school quality but also unobservable differences in the neighborhood environment (i.e., omitted variables bias).

In contrast, if we consider two houses, H_1' and H_2', within a very close proximity to each other, we can expect that two houses share almost the same neighborhood environment. At the same time, since two houses are still located in different school districts, the school quality they face will be different. Therefore, any difference in house price can be attributed to differences in school quality.

Figure 1. Boundary Discontinuity Design



In a regression framework, Black (1999) estimates hedonic regressions to a sample of houses that are very close to the attendance zone boundaries. In Figure 1, this corresponds to limiting the sample to houses located in a gray area near the attendance zone boundaries. If neighborhood characteristics other than school quality change smoothly at the district boundary, any discontinuous changes in house prices at the boundary are due to the discontinuous changes in school quality. Such an identification strategy is similar to the idea of regression discontinuity design, a quasi-experimental approach for policy evaluation, and is often referred to as boundary discontinuity (BD) design (Imbens and Lemieux, 2008; Lee and Lemieux, 2010).

The empirical results based on the BD approach show that a 5% increase (approximately one standard deviation) in average test scores would increase house prices by 1.3 to 1.6%. In contrast, standard hedonic regression models using full samples show that house prices increase by about 3.5% for an equivalent change in average test scores. These results suggest that the presence of an unobservable neighborhood environment leads to a large upward bias in the estimates of β.

The method is clearly innovative and, as discussed below, much of the recent empirical work on the same topic has employed identification strategies based on the BD approach. However, several problems have been recognized with this approach. One of the major problems concerns residential sorting across different school attendance zones. If families care about school quality and choose their residential location accordingly, the local socioeconomic characteristics may change discontinuously at the attendance boundaries.[6]

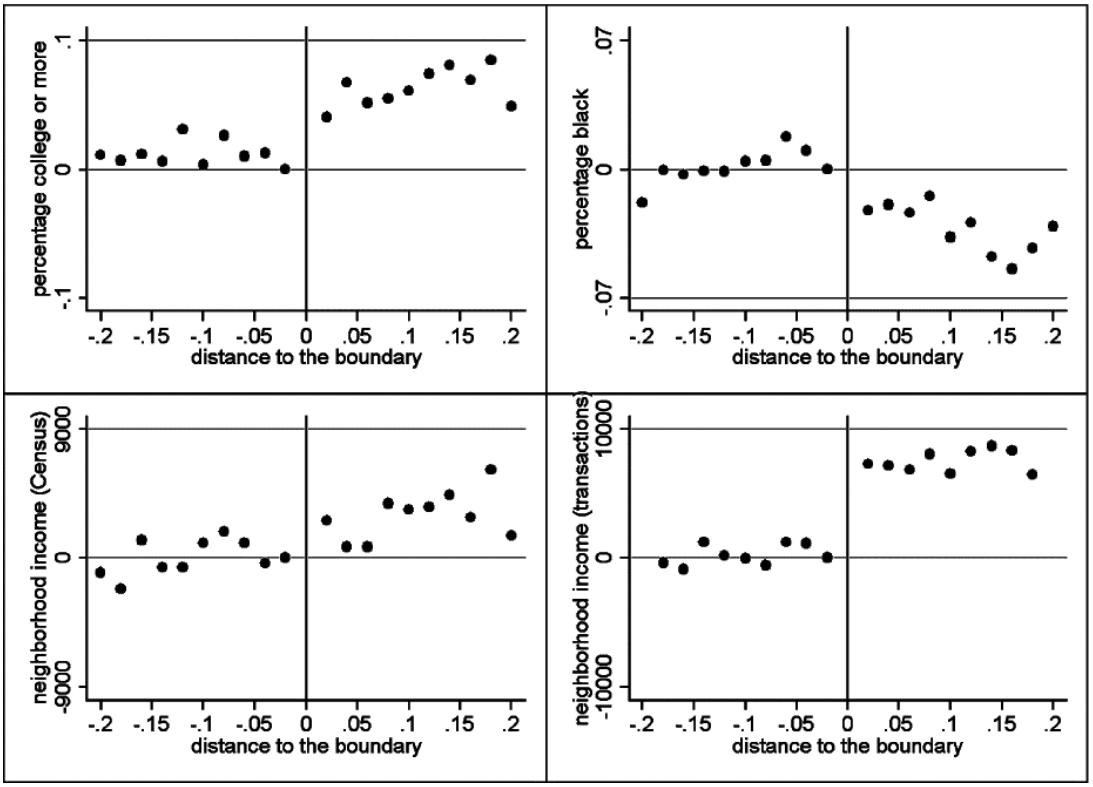
Figure 2 summarizes the movement of neighborhood sociodemographic characteristics in the region of school attendance boundaries (Bayer et al., 2007). Bayer et al. (2007) focus on boundaries for which the gap in average test scores on each side of the boundary is greater than the sample median (38.4 points). The figure shows average neighborhood sociodemographics—share of college graduates and black, and average household income—calculated at the census block level at a given distance to the school attendance boundary, where negative distances indicate the low test score side. On average, families in the high test score side of the boundary tend to have a higher education, earn a higher income, and are less likely to be black.

If households have preferences over their neighbors, residential sorting and discontinuous changes in neighborhood sociodemographic characteristics at the boundary can lead to biased BD estimates.[7] Returning to the example in Figure 1, if households have preferences for the racial composition of the neighborhood, the price difference between two houses H_1'

[6] Discontinuous changes in the neighborhood environment at attendance district boundaries can be caused by various reasons other than residential sorting. For example, when attendance district boundaries coincide with administrative boundaries, available public services and/or tax rates may change discontinuously at the boundary. In addition, if adjacent school districts are physically separated from each other by rivers, large roads, or other factors, the neighborhood environment can change significantly at school district boundaries. Therefore, these cases should be carefully excluded in the analysis.

[7] They extend the standard boundary discontinuity approach and develop a discrete-choice model of residential sorting, using boundary fixed effects for the identification of heterogeneous preferences for schools and neighborhoods. For more recent application of their approach, see Tra et al. (2013) for example.

Figure 2. Residential Sorting Across School Boundary



Source: Bayer et al. (2007, Figure 4).
Notes: The horizontal axis represents distance to the boundary, where negative values indicate the low test score side. The vertical axis represents average neighborhood sociodemographic characteristics for residents' education (% college degree or more), racial background (% black), and household income. The lower left panel uses census-reported household income, and the lower right panel uses household income from transaction data.

and H_2' near the attendance boundary would be affected not only by discontinuous changes in school quality but also by changes in racial composition of the neighborhood at the boundary.

Bayer et al. (2007) find that controlling for neighborhood sociodemographics (neighborhood racial composition and education) at the census block level yields substantially smaller BD estimates. Specifically, they show that the school quality effects on housing prices become approximately 50% smaller in BD models with neighborhood sociodemographic controls than in standard BD models with boundary fixed effects.

IV. Recent Empirical Evidence

In this section, we review major findings and methodological developments in recent empirical studies based on the hedonic approach. As mentioned earlier, given that several

surveys already exist on this topic, our review here covers a list of empirical studies mostly published after 2010. We include studies published before 2009 if they are not covered by previous surveys, especially those on Japan. The studies covered are summarized in Table 1. The following section provides an overview of the recent studies listed in Table 1 from three perspectives: identification strategies and empirical methods employed, the magnitudes of the MWTP estimates, and the specific research topics.

IV-1. Identification Strategies and Empirical Methods

As discussed in the previous section, the BD approach has become increasingly common in the literature. In fact, 17 of the 28 studies listed in Table 1 have employed BD design as the basic identification strategy. In contrast, Black and Machin (2011), which summarize studies prior to 2010, report that only 10 out of 54 papers in question employed a BD design.

On top of that, there are two major methodological features observed in the recent studies. First, even in empirical analyses that employ BD design as a basic identification strategy, an increasing number of studies are using some kind of time-series variation in school quality as an additional source of identification by using pooled transaction data from multiple points in time. For example, several papers employ a combination of BD and difference-in-differences identification strategies by focusing on events such as new school openings or changes in the geography-based attendance rules (Neilson and Zimmerman, 2014; Schwartz et al., 2014; Chung, 2015; Andreyeva and Patrick, 2017).[8] These cases will be discussed in more detail in Section IV-3-2.

Second, in response to the potential bias stemming from residential sorting, an increasing number of analyses control for neighborhood environments that can be correlated with school quality at the spatially disaggregated levels. Table 1 summarizes the spatial fixed effects that are controlled for in the empirical analysis (see "Fixed Effects" column), showing that many studies include fixed effects at the census block levels or their equivalent.

A notable example from this perspective is by Ries and Sommerville (2010). They employ an identification strategy that uses a time-series variation in school quality due to changes in school attendance zones, controlling for fixed effects at the housing unit level by using data on houses transacted multiple times during the sample period (i.e., repeat sales data). Their findings suggest that average test scores are positively associated with local house prices in the standard BD setting with boundary fixed effects, whereas BD estimates lose their statistical significance when controlling for housing unit-level fixed effects.

There are several recent papers that apply the "spatial differencing" approach that is built upon a standard BD model (Gibbons et al., 2013; Zheng et al., 2016). Suppose that the exact location of housing i is denoted by c_i (for example, by longitude and latitude). The

[8] However, large-scale events such as school openings and changes in attendance rules can change the equilibrium of the hedonic model itself, and there are several discussions on whether β identified by the non-marginal changes in school quality caused by these events can be interpreted as a marginal willingness to pay (Kuminoff and Pope, 2014; Banzhaf, 2018).

Table 1. Summary of Recent Empirical Findings

Study	Setting[(1)]	Data[(2)]	Method[(3)]	Fixed Effects[(4)]	School Quality[(5)]	Results	Notes
Agarwal et al. (2016)	Singapore	PC (N=135,788)	DD	N	TS	Yes	Test whether school relocation affects local housing prices.
Andreyeva and Patrick (2017)	US (Atlanta, GA)	PC (N=28,654) R (N=22,860)	BD + DD	B + C	OT	Yes	Test whether opening charter schools affects local housing prices.
Beracha and Hardin III (2018)	US (Miami, FL)	PC (N=116,386 (rental), N=198,747 (sales))	BD	B	TS	Yes	Compare the capitalization of school quality on housing rents and transaction prices.
Carrillo et al. (2013)	US (Fairfax County, VA)	C (N=37,258 (2001-2002), N=15,579 (2006-2007))	BD	S	TS	Yes	Test whether school information disclosure on the multiple listing services (MLS) affects local housing prices.
Chung (2015)	South Korea (Seoul)	PC (N=10,259 (rental), N=28,182 (sales))	BD + DD	B + P	OT	Yes	Test whether abolishment of geographic attendance rules affects local housing prices. Admission to the Seoul National U. as the measure of school quality.
Clapp et al. (2008)	US (CT)	PC (N=356,829)	FE	S + N	TS + SD	Yes	Compare results from various quality measures.
Conlin and Thompson (2017)	US (OH)	PC (N=2,225)	OT		IP	Yes	Estimate the impacts of school's facility investment financed by the state subsidy program on student outcomes.
Dhar and Ross (2012)	US (CT)	PC (N=68,288)	BD	B + BS	TS	Yes	Focus on school district boundaries rather than attendance boundaries.

Table 1 (continued). Summary of Recent Empirical Findings

Study	Setting[1]	Data[2]	Method[3]	Fixed Effects[4]	School Quality[5]	Results	Notes
Feng and Lu (2013)	China (Shanghai)	PC (N=2,496)	FE	N	OT	Yes	Test whether designation of "core high schools" affects local housing prices.
Fiva and Kirkebøen (2011)	Norway (Oslo)	PC (N=79,322)	FE	S	TS	Yes (short-run) No (long-run)	Test whether school information disclosure affects local housing prices.
Fleishman et al. (2017)	Israel	PC (N=5,666)	FE	S	TS	Yes	Test whether disclosure of average test scores affects local housing prices.
Gibbons and Silva (2011)	UK	C (N=560)	FE	S	TS + OT	Yes	Use subjective assessment of schools by existing students and parents as school quality measures.
Gibbons et al. (2013)	UK	PC (N=1,656,056)	BD + SP + OT	B	TS	Yes (average) Yes (value-added)	Compare results using average test scores and value-added measures.
Hwang et al. (2019)	US (Pitt County, NC)	PC (N=5,135)	OT	C	TS + IP	Yes	Take account of preference heterogeneity by employing finite mixture models.
Imberman and Lovenheim (2016)	US (Los Angeles, CA)	PC (N=63,122)	BD + DD	S	TS + IP	Yes (average) No (value-added)	Test whether school information disclosure affects local housing prices.
Kuroda (2018)	Japan (Matsue, Shimane)	C (N=2,642)	BD	B	TS	Yes	Test whether average test scores from the nationwide exam (Zenkoku Gakuryoku Chosa) affects local housing rents.
La (2015)	US (Boston, MA)	PC (N=20,674)	BD	N	TS	Yes	Exploit distance-based assignment to the local public schools.

Table 1 (continued). Summary of Recent Empirical Findings

Study	Setting(1)	Data(2)	Method(3)	Fixed Effects(4)	School Quality(5)	Results	Notes
Machin and Salvanes (2016)	Norway (Oslo)	PC (N=16,330)	BD	B + S	TS	Yes	Test whether school choice programs affect local housing prices.
Mothorpe (2018)	US (DeKalb County, GA)	PC (N=22,604)	BD	B	TS	Yes	Compare school quality capitalization between areas with expected changes in attendance zoning and those without.
Neilson and Zimmerman (2014)	US (New Haven, CT)	PC (N=14,266)	BD + DD	N	OT	Yes	Test whether new school openings affects local housing prices.
Ries and Somerville (2010)	Canada (Vancouver, BC)	R (N=87,381)	BD / FE	B / P	TS	No (elementary) Yes (junior high)	Test whether changes in attendance zones affects school quality capitalization. Significant estimates when using BD.
Rosburg et al. (2017)	US (Cedar Falls, IA)	PC (N=434)	DD + SP		OT	Yes	Test whether closing a high-quality school (Malcom Price Laboratory School) affects local housing prices.
Schwartz et al. (2014)	US (New York, NY)	PC (N=352,291)	BD + DD	B + S	TS	Yes	Test whether opening a “choice school” admitting students outside of original attendance zones affects local housing prices.
Tra et al. (2013)	US (Las Vegas, NV)	C (N=31,364)	BD	B + C	TS	Yes	Compare results from hedonic models with those from equilibrium sorting models.

Table 1 (continued). Summary of Recent Empirical Findings

Study	Setting(1)	Data(2)	Method(3)	Fixed Effects(4)	School Quality(5)	Results	Notes
Turnbull et al. (2018)	US (Orange County, FL)	PC (N=127,120)	BD	S + N	TS + SD + IP	Yes	Examine the housing price effects of school quality and quality uncertainty.
Ushijima and Yoshida (2009)	Japan (Tokyo 23 wards)	R (N=32,445)	FE	S + P	OT	Yes	Use private junior high school attendance as a measure of elementary school quality and estimate its impact on local land values.
Yoshida et al. (2008)	Japan (Adachi, Tokyo)	R (N=3,917)	FE	S + P	TS + OT	Yes	Compare results using different quality measures (private school attendance and average test scores). Test whether introduction of school choice programs affects school quality capitalization.
Zheng et al. (2016)	China (Beijing)	C (N=226)	OT		OT	Yes	Compare within and out-of-zone housing prices in adjacent buildings. Control for unobserved neighborhood quality using the rental differentials between paired observations.

Notes and abbreviations:
(1) Region (city/county and state for the U.S. and Canada; city and prefecture for Japan, and city for other countries) in the parentheses.
(2) C: Cross-sectional; PC: Pooled cross-sectional; R: Repeat sales or panel.
(3) BD: Boundary discontinuity design; DD: Difference-in-Differences; FE: Fixed effects models; SP: Spatial econometric models; OT: Other methods
(4) Level of neighborhood fixed effects. B: Boundary fixed effects; BS: Boundary fixed effects for both sides; N: Neighborhood (e.g., census block) fixed effects; S: School attendance zone fixed effects; C: Administrative units (e.g., cities or counties) fixed effects, P: Property unit fixed effects.
(5) Type of school quality measures. TS: Test scores (incl. rankings based on test scores); SD: Schools sociodemographic characteristics; IP: School resources/inputs (e.g., per pupil expenditure, student/teacher ratio); OT: other quality measures.

spatial differencing approach compares prices between pairs of housing *i* and *j* that are located in different school zones ($s_i \neq s_j$) but within a close proximity to each other ($|c_i - c_j| < \delta$).

$$p_i - p_j = \beta(s_i - s_j) + (\tilde{\mathbf{z}}_i' - \tilde{\mathbf{z}}_j')\tilde{\boldsymbol{\gamma}} + (\tilde{\varepsilon}_i - \tilde{\varepsilon}_j) \quad (4)$$

This would remove the influence of any unobservable spatial factors shared between housing *i* and housing *j*.

IV-2. Comparing MWTP Estimates

Table 1 shows that almost all studies indicate that school quality is positively associated with local house prices, which is also reported in previous surveys (Black and Machin, 2011; Nguyen-Hoang and Yinger, 2011).[9]

If we look at empirical results using average test scores as a measure of school quality, recent estimates suggest that a one-standard deviation improvement in average test scores will increase local housing prices by approximately 0.7 to 3%. Specifically, the impact of a one-standard deviation increase in average scores on house prices is 1.3% in Clapp et al. (2008), 1.5% in Fiva and Kirkebøen (2011), 2.8-3.0% in Gibbons et al. (2013), 2.4% in Kuroda (2018), 0.7-1.3% in Ries and Sommerville (2010) and 1.4% in Turnbull et al. (2018).[10]

Two things are worth noting from these results. First, recent MWTP estimates for school quality are substantially smaller than those from earlier studies. The comparable estimates from earlier studies, among others, are 14% by Downes and Zabel (2002), 9.8% by Cheshire and Sheppard (2004), 7.1% by Brasington and Haurin (2006), all of which are substantially larger than the recent estimates.

The decline in MWTP estimates in recent studies is perhaps due to methodological updates discussed in the previous section. In fact, all of the recent studies discussed above either use a BD approach or control for fixed effects at fairly disaggregated geographic levels (such as census blocks). In comparison, all of the earlier studies above use a standard regression-based method other than BD. These results are consistent with the notion that unobserved neighborhood characteristics is likely to bias upward the standard regression-based estimates of the value of school quality.

A second key insight from the recent MWTP estimates is that they do not differ substantially across countries. The recent estimates presented above are for the U.S., Canada, the UK, Norway, and Japan, where there are huge differences in institutional settings, in terms of public education and tax systems. A quantitatively similar MWTP estimate supports the external validity of the hedonic approach to some extent.

[9] An exception is by Ries and Sommerville (2010). However, even in this study, the average junior high school test scores are found to have a significant positive effect on house prices.

[10] In order to quantitatively compare estimates from different studies, we limit our case to studies using average test scores as a measure of school quality.

IV-3. Specific Topics in the Literature

This section provides a detailed overview of recent studies on several specific topics. We cover three specific topics: (1) comparing estimates from alternative measures of school quality; (2) exploiting specific events such as new school openings, relocations, and attendance boundary changes as an additional source of school quality variation; and (3) focusing on the release of school quality information.

IV-3-1. Comparing Estimates from Alternative Quality Measures

As discussed in Section II, there are a number of potential school quality measures, while most recent studies use average test scores as a measure of school quality. These quality measures other than average test scores include, among others, value-added measures of student achievement, school resources such as expenditure per pupil, student/teacher ratio or teacher quality, and the school's peer composition. There are some important papers in the literature that investigate the impact of other potential quality measures, which we consider in turn.

With the help of student-level longitudinal data and methodological development, there are several papers that investigate the impact of value-added measures of student achievement on local house prices. The student-level value-added measures evaluate the same student's improvement over time on the same test. This is typically estimated by using a student-level longitudinal dataset. In the literature, these student-level measures are aggregated at the school level to obtain a school-level value added.

Gibbons et al. (2013) and Imberman and Lovenheim (2016) both estimate the impact of school-level value added on local house prices and compare these estimates with those using average test scores. Their empirical analyses shows contrasting results. Gibbons et al. (2013) show that both average test scores and value-added measures are positively associated with local house prices. In contrast, Imberman and Lovenheim (2016) find that, while average test scores do have a significantly positive effect on local house prices, the measure of value added does not. Although it is difficult to pin down the exact reason for the discrepancy between these empirical findings, there are significant methodological differences between the two studies. While Gibbons et al. (2013) estimate a standard BD model, Imberman and Lovenheim (2016) further exploit a series of information releases about school's value added to estimate difference-in-differences models combined with a BD strategy.

Another important measure of school quality comes from school resources. In this regard, Conlin and Thompson (2017) analyze the effect of school's capital expenditures on local housing prices. Specifically, they use a state government's capital subsidy program as a source of exogenous variation in school's expenditures and test whether exogenous changes in school's expenditure affect student achievement and house prices. They find that increased expenditures on school facilities have a negative impact on student achievement in the short-run, but have a positive impact in the long-run. Correspondingly, they also find

that capital expenditures have a negative impact on house prices in the short run and a positive impact in the long run.

IV-3-2. School Opening, Relocation, and Boundary Rezoning

As discussed in Section IV-1, recent empirical studies in the literature increasingly rest on school quality variation due to policy changes. For example, school attendance zone boundaries can be adjusted for various reasons. Such rezoning provides substantial cross-sectional and time-series variations in school quality, which can be used together with boundary discontinuity to identify school quality effects on house prices.

This line of research focuses on school openings and closures (Andreyeva and Patrick, 2017; Neilson and Zimmerman, 2014; Rosburg et al., 2017; Schwartz et al., 2014), school relocations (Agarwal et al., 2016), and attendance boundary changes (Chung, 2015; Ries and Sommerville, 2010). These empirical studies aim to identify the school quality effects by comparing house prices in locations subject to policy-driven changes in school quality with those in locations not affected by the policy. As a result, most of these studies adopt a difference-in-differences-type identification strategy often in conjunction with BD-type strategy. A general finding in these studies is that school quality is positively associated with local house prices.

While this type of analysis has made substantial progress towards obtaining more credible MWTP estimates of school quality, there are a number of limitations. First, major policy changes, such as school openings and boundary rezoning, may be caused by some (often unobservable) neighborhood changes that also affect housing prices. For example, new school openings are often in areas with increasing population. The underlying causes of population increase, however, might also affect local house prices in the area. Without knowing these underlying causes, the impact of school openings on house prices will still be biased. Second, careful consideration should be given to the applicability of the results obtained under specific policy changes to the more general situation. Indeed, some results suggest that school quality has a smaller impact on housing prices in situations where school boundary rezoning is expected (Mothorpe, 2018; Turnbull et al., 2018).

There are also studies focusing on the introduction of school choice programs (Chung, 2015; Machin and Salvanes, 2016; Yoshida, Zhang and Ushijima, 2008). The introduction of school choice programs may weaken the relationship between school quality and housing prices since it allows students to go to schools other than those assigned under the existing attendance rules. The results of the above analysis all support these hypotheses.

IV-3-3. Release of School Quality Information

In recent years, school accountability increasingly has become an important issue in public education. As a result, many school districts in the U.S. have begun to release school quality information to the public. Given such policy trend, a natural research question is whether, and to what extent, the new information on school quality affects local housing prices. The earliest empirical study on this topic is by Figlio and Lucas (2004), focusing on

the release of school report cards in Florida. Since then, there has been a growing body of research in recent years (Carrillo et al., 2013; Feng and Lu, 2013; Fiva and Kirkebøen, 2011; Fleishman et al., 2017; Imberman and Lovenheim, 2016).

All of these studies aim to identify the school quality effects by looking at how local house prices change after the release of school information. Fiva and Kirkebøen (2011) examine the release of school ranking information in Norway (Oslo). Their results show that while the new school information has increased local house prices, these effects are observed only for a short period of time (two to three months) following the release, after which they return to the pre-release baseline. Imberman and Lovenheim (2016) examine the release of school's value-added information in Los Angeles. Using a combination of a BD design and a difference-in-differences approach, they find that new value-added information does not have any significant effect on local housing prices. The fact that additional information about school quality does not affect house prices (at least in the long run) is an important finding, as it is at odds with previous findings. Nonetheless, households may garner some, if not precise, information about school quality even before the formal release. In this case, school quality information from the public release may not be entirely "new" to each household, leading to insignificant effects of the information releases on local housing prices. Another interpretation of the Imberman and Lovenheim's (2016) results is that, since they focus on the new release of value-added information, families care about schools' average test scores but not about their value added.

V. Evidence from Japanese Data

Earlier studies in the literature are predominantly from the U.S. and several western countries, and there has been relatively few studies from other countries, especially from Japan. This section reviews relatively scarce evidence from Japan and discusses how Japan's case can contribute to the literature.

The main reason for scarce empirical studies in the Japanese setting is probably due to the lack of school quality data, particularly those for test scores. As a result, previous studies have used measures of school quality other than average test scores. For example, Yoshida, Zhang and Ushijima (2008) use enrollment in private junior high schools as an alternative quality measure of elementary schools. Their empirical analysis, using land price data for Adachi Ward in Tokyo, shows that a 10% increase in the share of private school enrollment among graduates results in a 2.6% increase in land prices within the school district.[11] They also find that school quality capitalization into land prices becomes less pronounced after the introduction of the school choice program. Ushijima and Yoshida (2009) use the same measure of school quality and expand the analysis to cover the 23 wards in Tokyo. They also find that higher school quality increases land prices within a school district, and that

[11] They also conducted an analysis using average test scores. However, these test score measures are available for shorter time period (2005 and 2006), leading to the relatively imprecise estimates from these models.

school quality effects on land prices are more pronounced in areas that have higher-quality schools.

More recently, Kuroda (2018) estimates the impact of schools' average test scores on local housing rents in Matsue City, Shimane Prefecture. This was made possible by the release of average test scores by Matsue City. A standard BD analysis shows that average school-level test scores have a significantly positive effect on local housing rents, and that this is primarily driven by the positive impact on housing rents for relatively large houses (which are presumably for families with school-aged children).

The empirical analysis for Japan's case can have several advantages in terms of its institutional settings and available data. The first advantage relates to reverse causation. As discussed in Section II, reverse causation can be a relevant empirical issue in the U.S. context where local property taxes generate causality running from local house prices to school quality via public expenditure on schooling. In contrast, public school expenditure is determined at the municipal level in Japan and is, in principle, not directly related to local house prices within the district. As a result, reverse causation due to local property taxes is not an issue in the Japanese context. The second advantage concerns geographic attendance zoning and student allocation across public schools. As discussed in Section II, a matching between housing locations and schools based on attendance zoning is an important basis for the BD analysis. In Japan, the attendance zoning rule is relatively strictly enforced, ensuring the validity of the BD analysis. In addition, open enrollment or school choice programs are not very common in the Japanese setting. In Japan, a 1997 notification by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) ("On the Flexible Operation of the School District System") allows for the introduction of a school-choice system at the discretion of municipal boards of education. However, as of 2012, 81.9% of municipal boards of education have not introduced the school choice system and have no plans to do so (MEXT, 2012). The third advantage comes from the available data for housing valuations. In Japan, appraisal-based land prices are available from the Public Notice of Land Prices (PNLP; *Chika Koji* in Japanese). The PNLP, which is published annually, provides appraisal land values for specific sites. An important feature of this dataset is that there are repeated observations for the same site over time, leading to the panel structure. Making use of such data structure, Yoshida et al. (2008) and Ushijima and Yoshida (2009) estimate fixed-effects models to identify the impact of school quality on land prices, allowing them to control for time-invariant unobservable characteristics of sites and neighborhoods.

There are, however, several empirical challenges and limitations of Japanese studies. Most notably, school-level achievement measures, such as average test scores, are still not readily available. In Japan, a nationwide academic testing program (the National Assessment of Academic Ability and Learning Environment; *Zenkoku Gakuryoku Gakushu Jyokyou Chosa* in Japanese) has been conducted since 2007. However, school-level achievement measures have not been made public, with exceptions in few local governments, and the use of an original dataset has been widely restricted even for academic purposes. As a result, the lack of school quality measures substantially hinders empirical analysis that is

comparable to existing evidence from other countries.

In addition, academic testing discussed above aims to evaluate student's achievement at a single point in time and is not designed to evaluate the same student's improvement over time. Since the Japanese testing program covers virtually all students in grades 5 and 8, it is possible, in principle, to track the same student's achievement over time. However, the current survey design does not allow this (i.e., no unique student identifier in the survey). As mentioned above, the use of schools' value added has been increasingly common in the hedonic literature but the current Japanese setting does not allow this type of analysis.

In summary, while the Japanese setting provides unique opportunity to identify the causal effects of school quality on local housing prices, the lack of an adequate dataset, particularly in terms of student achievement, has been a major limitation of research. There is significant room for further research on this topic as more data on schools and students becomes available.

VI. Conclusion

This paper reviews school quality capitalization studies and discusses key methodological improvements in the literature. Section V also reviews several empirical findings from the Japanese data and discuss how Japan's case can contribute to the literature.

A key takeaway from our review is that there have been major methodological updates in the literature, moving from a traditional regression-based approach to a "quasi-experimental" method that seeks to exploit an exogenous source of school quality variations. Specifically, a BD approach proposed by Black (1999) has become the *de facto* method of analysis. More recent studies further focus on specific events like school openings and boundary rezoning, and exploit additional source of school quality variation, in combination with boundary discontinuity, in order to obtain more credible MWTP estimates for school quality.

Perhaps as a result of these methodological updates, we find that recent MWTP estimates for school quality are substantially smaller than those from earlier studies. This is consistent with the notion that empirical results from earlier studies are likely biased upward due to unobserved neighborhood characteristics. Nonetheless, we also find that most empirical evidence to date shows a significantly positive impact of school quality on local housing prices. Furthermore, a comparison of empirical results from various countries shows that MWTP estimates are markedly similar despite the huge differences in their institutional settings, which ensures the external validity of the approach to some extent.

There are several emerging topics in the literature. For example, several recent studies focus on specific policy changes including school openings/closures, boundary rezoning, and the release of new information on school quality. These analyses complement the BD approach where identification comes both from discontinuous changes in school quality at the boundary and from policy-driven changes. Another example is studies that focus on the role of alternative quality measures such as schools' value added and educational resources. These analyses have significant policy implications in that they can answer how and to what

extent families evaluate various school characteristics.

Finally, looking at the current state of research in Japan, there is a stark contrast to the rapid accumulation of evidence from the U.S. and several western countries. We argue that the Japanese setting can potentially contribute to the literature, and there is much room for further research in Japan with the help of more data on schools and children.

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