SCHOOL QUALITY AND RESIDENTIAL PROPERTY VALUES: EVIDENCE FROM VANCOUVER REZONING

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Abstract—This study utilizes changes in the catchment areas of public schools in Vancouver, British Columbia, to measure the residential price capitalization of school quality. Specifications that employ repeat sales methods to control for time-invariant neighborhood effects and disaggregated price indexes to capture time-varying neighborhood price appreciation reveal significant effects of secondary school performance on residential prices. However, when we add controls for long-run price trends in rezoned areas, only prices of residences likely to be purchased by high-income families appear to have been affected by changes in school quality induced by rezoning.

I. Introduction

IN September 2000, the Vancouver School Board announced plans to adjust the catchment area boundaries of public elementary and secondary schools. Affecting roughly 20% of residences in Vancouver, British Columbia, the new boundaries became effective in January 2001. Since the quality of local public schools appears to play a prominent role in housing choice decisions, we use the rezoning as a natural experiment to identify parental valuation of school quality as it is capitalized in residential real estate prices in Vancouver.

Our primary approach relates the change in school quality that results when a residence is reassigned to a different catchment area to changes in the residence's transaction price. Our measures of school quality are primarily based on standardized test scores. The rezoning allows us to identify school effects based on the substantial cross-sectional variation in school quality. Repeat sales data enable us to control for time-invariant unobserved characteristics of residences and neighborhoods.

To capture neighborhood price changes, we employ two sets of controls. First, we measure changes occurring at highly localized areas by creating neighborhood price indexes using a Fourier transformation that enables us to estimate "smooth" indexes using limited data. In order to measure school quality effects, these neighborhoods, while finely disaggregated, must encompass a larger set of residences than those that were rezoned from one school to another.[1] As a second control, we use information on transactions prior to the policy announcement to capture price trends occurring in neighborhoods subject to the rezoning.

There is a long literature that uses hedonic pricing techniques with data on housing prices, housing characteristics, and school performance, typically student test scores, to measure the capitalization of school quality into housing prices. These efforts began with Oates's (1969) work on per student expenditures and average house values using a sample from northern New Jersey. This and other work using hedonic price equations to link cross-sectional variation in house prices and school quality are subject to bias from unobserved neighborhood effects correlated with school performance. As well, there may be selection bias if people with unobserved heterogeneous attributes systematically select into certain neighborhoods. Given the correlation of household income, house prices, local amenities, school resources, and student quality, the potential for bias is acute.

Black (1999) controls for unobserved neighborhood effects by comparing variation in house prices across the border separating two attendance districts, where the sample is limited to houses within a narrow band along the border.[2] When she adds "boundary fixed effects," the positive effect of elementary test scores drops by approximately 50% but remains statistically significant and large—a 1–standard-deviation increase in elementary test score (5% increase) corresponds to a 1.8% to 2.1% increase in house value.

Bayer, Ferreira, and McMillan (2007) advance Black's methodology by controlling for variation in neighborhood sociodemographics. Black's method yields positively biased estimates if school quality is correlated with unobserved household sociodemographic differences that arise from sorting. They find that controls for household characteristics reduce the coefficient on school quality by about 50% from the estimate obtained in Black-type specifications. In a discussion of the limitations of their study, however, they acknowledge that "the empirical strategy . . . does not address the possibility that the higher-income households on the higher test score side of a school boundary might be more likely to make home improvements (install granite countertops, e.g.) unobserved by the researcher, in turn contributing to the higher average house prices on that side of the boundary" (p. 593).

Gibbons and Machin (2003) use an instrumental variable approach to investigate primary school performance and housing prices in England using mean housing price data for 7,444 "postcode sectors" in the years 1996 to 1999. They estimate a hedonic regression using instrumental and semiparametric techniques. Information on school type

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[1] The indices and school change variables would be collinear if they were based on the same set of residences.

[2] Black's use of boundary dummies is a more refined application of the boundary analysis used in Gill (1983) and Cushing (1984).

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serves as the instrument for school quality. Despite the leakage because students have some choice in where they can enroll, Gibbons and Machin find a positive effect of local school quality on house prices: a 1 percentage point increase in the proportion of children meeting an education target raises property values by 0.67%.

A small number of recent studies utilize repeat-sales information to control for unobserved time-invariant characteristics of properties and neighborhoods. Figlio and Lucas (2004) investigate how the assignment of state-administered letter grades to elementary schools in Florida influenced house prices. Their specification includes property and year-neighborhood fixed effects, and their estimates are based on within-year variation in house prices for each neighborhood around the July announcement of school grades. They find that the effect of the grades decreases over the three years of announcements and generally becomes insignificant over the full period.[3] The authors interpret this diminishing effect as stemming from volatile grades: over a three-year period, over half of all schools rated A, B, or C received at least two different grades. While they include school test scores in their regressions, coefficients are not reported for these variables.

Downes and Zabel (2002) use an instrumental variables approach to compare the effects of school input and output measures on house prices using owner-assessed home values in 1987 and 1991 for 743 homes in Chicago. They employ the proportion of the tax base that is residential, per pupil assessed value, the proportion renting, and the proportion of the population that is school aged as instruments for eighth-grade school reading scores. It is unclear whether these are valid instruments since one can argue that they have a direct influence on owner-assessed house values. The authors also include controls for neighborhoods (census information) and schools (for example, characteristics of students and school expenditure levels). In their first-difference specification, eighth-grade reading scores exert a significant effect on owner-assessed values with an elasticity equal to 1. One shortcoming of their study is that unless the instruments they use are valid, the estimates of school test score effect may be positively biased due to unobserved changes in neighborhoods. Furthermore, they use owner-estimated value rather than transaction price. This can bias their coefficients upward since with rising house prices, owners are more likely and better able to finance home renovations, which they tend to overvalue (DiPasquale & Somerville, 1995).

As we do for Vancouver, Bogart and Cromwell (2000) take advantage of the natural experiment afforded by school attendance zone boundary realignment. They look at the effect of redistricting on single-family house prices when the number of elementary schools in Shaker Heights, Ohio, was reduced from nine to six. Using both hedonic and repeat-sales approaches, they find that realignment had large negative effects on housing prices but that houses that kept their neighborhood school and received school bus service appreciated in value. Their hedonic regressions find that third-grade reading scores are negatively associated with housing prices, presumably a result reflecting bias due to omitted neighborhood effects. While they do not report the actual estimates of the coefficients on the reading scores in the repeat-sales analysis, they state that they "are positive (with one exception) and usually statistically significant" (p. 304). Their sample has few school changes, and they occur within a relatively homogeneous upper-middle-class suburb.

Our unique data allow us to contribute to the literature in a number of ways. First and foremost, rezoning enables us to estimate school quality effects based on times series variation in house prices and substantial cross-sectional variation in school performance. Repeat sales information allows us to control for unobserved, non-time-varying attributes of neighborhoods, residences, and residents. Use of cross-sectional school performance information is extremely important in light of Kane and Staiger's (2002) finding that 70% of within-school variation in elementary school test scores is nonpersistent. Our rich data set, comprising 87,381 repeat sales transactions and information on 18 secondary and 69 elementary schools, enables us to estimate the effects of school quality using a wide range of specifications and disaggregated neighborhood price indexes. In addition, since we focus on a single municipality, residents in different neighborhoods face uniform tax rates and levels of city services. Finally, information on structural characteristics of residences enables us to investigate how effects of school quality vary across types of residences.

The paper proceeds as follows. Section II provides details about the rezoning. Section III describes the data on school quality and residential transactions and identifies the areas of the city where the rezoning led to large changes in school quality. Section IV specifies our empirical strategy and explains the Fourier transformation techniques we use to compute price indexes for narrow geographic areas. Section V contains regression results.

We begin by estimating school quality effects using hedonic regressions based on cross-sectional house information of schools and residences. We employ different types of neighborhood fixed effects, including the same boundary neighborhood effects used in Black (1999), and we find results that concord with the literature by identifying large and significant positive effects of school test scores on house prices. We follow this with our repeat sales regressions. These include different alternative neighborhood price indexes and specifications that allow the coefficient on school quality to vary depending on whether the residence is likely to be family owned or purchased by a high-income buyer. Finally, we use transaction data for a period prior to the boundary change announcement to capture price trends occurring in rezoned neighborhoods. With

[3] The exception is house prices in school zones where the school in question received an A grade in every year of the analysis.

the full set of controls, only residences likely to be purchased by high-income families appear to have been affected by rezoning. The final section summarizes the results and interprets them in the context of the existing literature.

II. Vancouver School Rezoning

The Vancouver School Board (VSB) made the rezoning proposal public in September 2000. The stated objective of the rezoning was to alleviate overcrowding in certain schools, although an examination of the changes reveals that many boundaries were adjusted to coincide with major street arterials. It was the city's first such rezoning, and the announcement appeared to come as a surprise to the public.[4] The proposed adjustments were approved with only minor changes in January 2001 and took effect with the new school year in September 2001. The change included grandfather clauses for both existing students and any younger siblings not yet in school who would attend a school at the same time as did an older sibling.

Most of the border adjustments were modest changes and involved multiple schools. For example, the geographic area for Lord Nelson Elementary School increased 12% as six city blocks were assigned away to one school and seventeen city blocks were assigned to Nelson from four different schools. Eric Hamber Secondary School gained from five adjacent school areas while transferring area to one other school.

Alternatives to local public schools in Vancouver include public French immersion, private schools, and cross-boundary admission to other VSB schools. As we detail in the appendix, each alternative has its drawbacks, and all typically involve greater travel to schools relative to attending the local school. French immersion may not be for everyone, entry is uncertain, and there are only a small number in the city. Private schools are costly. Critically, the likelihood of entering a specific good public school as a cross-boundary applicant is uncertain at best.

There are advantages to studying school quality in Vancouver. By using a single municipality, there is a single tax rate and a more standardized level of municipal services than would be the case if we were examining the relationship across jurisdictions. Also, the racial issues that so pervade location decisions in the United States are not as present.[5] Second, house preference and location are somewhat unbundled. Vancouver's housing stock is heterogeneous, with attached and condominium units making up less than 5% of the transactions in only five of thirty neighborhoods. Thus, we have a sample where preference sorting by house type is less likely to explain our results than in a suburban sample.

III. Data

A. *Measuring School Quality*

Information on student performance for public schools is available for Vancouver's 69 elementary and 18 secondary schools. Elementary school students take the Foundation Skills Assessment (FSA) exam. Secondary school students take provincial examinations.

Elementary schools. The FSA examinations are taken in three subjects—reading comprehension, writing, and numeracy—by fourth- and seventh-grade students. Since 2000, summary results by school have been made available in the fall for the exams taken in late spring of that year. For each elementary school, the results show the number of students who "exceed expectations, "meet expectations," and are "not yet within expectations" for each of the three exams.

There are many ways to compile measures of school performance from these data. We choose to aggregate scores across examinations and grades as follows. For each exam, we multiply the percentage of students who exceed expectations by 1 and the percentage who are not yet within expectations by –1. Then we sum the two (implicitly we are multiplying the percentage that meets expectations by 0). The upper and lower bound of this measure are 100 and –100. Then we average the six exams (two grades taking three exams each) for each school in a particular year. The correlation of the scores across the years 2000–2003 ranges between .68 and .80, indicating that although they are highly correlated, there is some variation in individual test scores across years for a given primary school. Kane and Staiger (2002), employing information on elementary school test scores in North Carolina, establish that 70% of year-to-year changes in class scores are nonpersistent. This large random variation in year-to-year changes in school performance strongly suggests that it is better to identify school effects using cross-sectional rather than temporal changes in scores for a given school. Given that one year's test score seems to be a fairly noisy measure of school quality, we use the average of the period over which we have data to measure the cross-elementary school variation in quality.[6] The average across all the schools for the four years 2000–2003 is –7.3, indicating that more students do not meet provincial expectations than exceed expectations in Vancouver public elementary schools. The scores range from 14.9 to –47.6, with a standard deviation of 11.1.

[4] One coauthor searched for a home in the spring 2000. Real estate agents did not mention pending boundary changes even for houses in areas that ultimately were rezoned into better schools.

[5] If black children tend to attend lower-quality schools and whites will pay not to locate near blacks, the school quality measure in a cross-section will pick up this unobserved race effect.

[6] This creates a potential time inconsistency problem in our empirical analysis where we use transactions that occur prior to the year in which some grades are reported. When we limit the analysis to using scores reported prior to the transaction date to measure school quality, our qualitative results are unchanged, but the standard errors are slightly higher. Allowing for time series variation in elementary school quality has no notable effect on the results.

FIGURE 1.—VANCOUVER ELEMENTARY SCHOOLS SCALED TEST RESULTS, 2000–2003

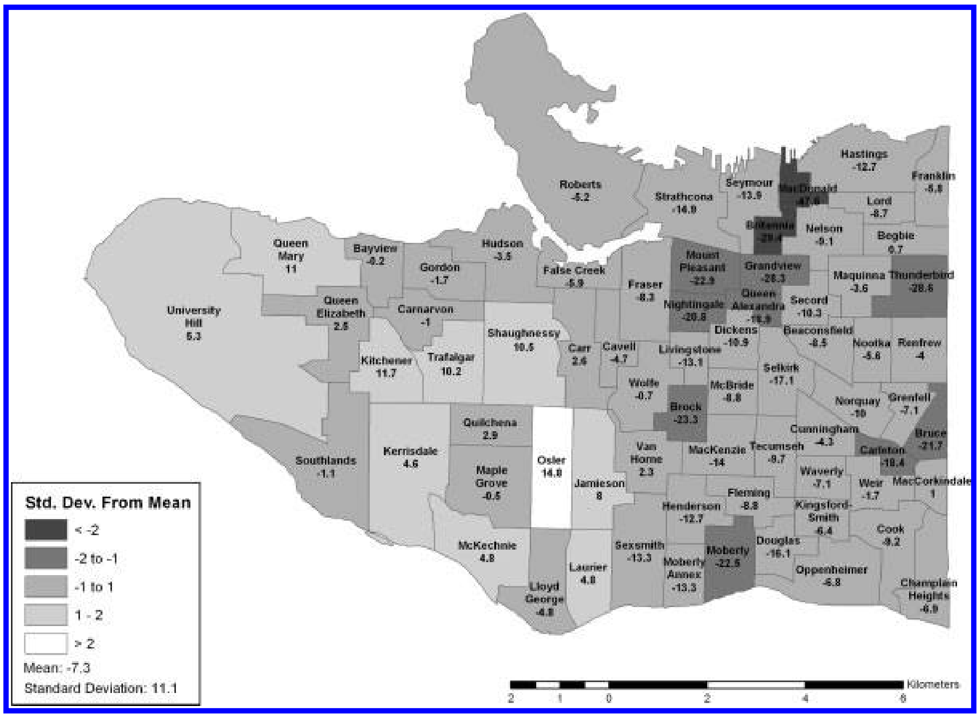


Figure 1 shows the postrezoning elementary school boundaries and the average 2000–2003 scores by school. The figure reveals that the better schools are on the wealthier west side of Vancouver.[7] There is a fair amount of variation in east side schools. For example, MacDonald, the lowest-ranked school, with an average score of –47.6, borders Nelson, a school with an average of –9.1 (near to the overall average). If school rezoning moves a house from MacDonald to Nelson, these units would now be zoned into a school with students who perform much better on the FSA.

Secondary schools. For secondary school quality, we use the rankings of the Fraser Institute, a nonpartisan think tank located in Vancouver. The institute gives each school a score on a 10-point scale based on eight criteria.[8] The key data are from the provincial examinations usually taken by twelfth-grade students. The mathematics and English exams are mandatory and constitute part of students' marks in the course. In addition, students may choose to take provincial exams in other subjects. The correlation between secondary school scores for the years 2000, 2001, and 2002 and the average of the five years ending in year 2000 are all 0.91 or higher, much greater than that for elementary school provincial test scores. We use the 1996–2000 average Fraser Institute rankings to measure secondary school quality in the empirical work. Thus, our measure reflects the reputation of the schools just prior to the rezoning announcement.

Figure 2 shows the postrezoning boundaries of these schools and their 1996–2000 Fraser Institute score (multiplied by 10). There is substantial variation in performance across schools: University Hill, located on the west side near the University of British Columbia, received a five-year score of 95.2, whereas John Oliver, on the east side, has a score of 40.6. The figure shows that except for the downtown core, west side schools perform uniformly better than east side schools. After rezoning, Main Street, which runs north to south, divides the Hamber-Tupper, Churchill-John Oliver catchment areas. A swath of neighborhoods on to the west of Main Street, zoned originally in poorly performing Tupper and Oliver, moved to west side schools Hamber and Churchill with the boundary changes. These neighborhoods will be critical sources of variation in school quality in our regression estimates.

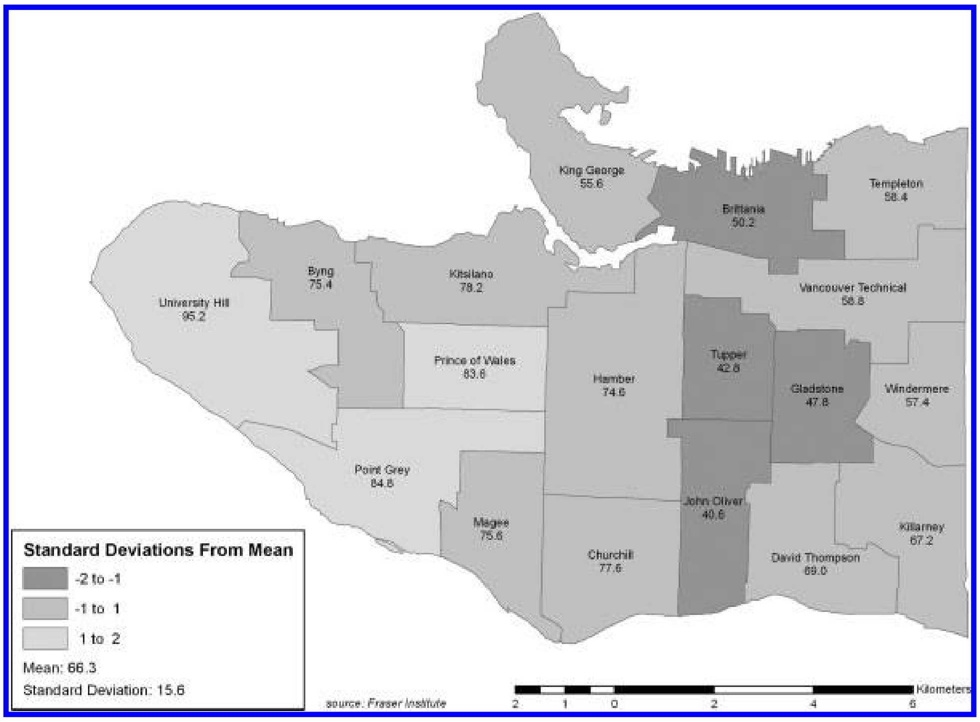
B. House Price Data

Our housing data are based on the complete universe of residential transactions in Vancouver for the period 1996–2003. The data are provided by Landcor from the British Columbia Assessment Authority (BCAA) records of

[7] The mean west side house price is $414,500, while on the east side it is $283,000, though unit area and lot size are nearly the same.

[8] The components of the Fraser Institute rankings and their associated weight in the overall score are: average exam mark, 20%; percentage of exams failed, 20%; school versus exam mark difference, 10%; English gender gap, 5%; math gender gap, 5%; exams taken per student, 20%; graduation rate, 10%; and composite dropout rate, 10%. The "school versus exam mark difference" indicates when provincial exam marks deviate from marks awarded in the school, and the gender gap indicates differences in male and female exam performance relative to average performance in the school. Each of the eight components is converted into a *Z* score before the weighting is applied.

FIGURE 2.—VANCOUVER SECONDARY SCHOOLS AVERAGE FRASER INSTITUTE SCORES, 1996–2000



transactions determined to be arm's length. We then obtain all previous sales for each of these transactions, back to 1974, discarding transactions from 1996–2003 that do not have a paired sale after 1974. Thus, unlike most repeat sales indexes that discard large amounts of data by looking only at units that transact twice over a limited time period, we ensure that we have observations for nearly all transacting units in our period of interest.[9] In addition to new units that transacted only once over 1996–2003, we also discard units with commercial and residential properties mixed together, those that transact twice on the same day, and those with transaction prices below $10,000 per unit. One of the problems with repeat sales analysis is that the user typically must assume that all structure characteristics have remained constant over time. As the time period of analysis grows, this assumption becomes more problematic, as property owners are likely to engage in significant repairs, renovations, and additions to their properties. This is especially likely in a housing market like Vancouver where house prices have risen substantially over time. The data set reports only current unit structure characteristics, so we are not able to track changes in unit size over time.[10] However, BCAA does include a variable that indicates its assessment of the interior vintage of a residence, which tracks renovation date. We use this to control for major structural changes by designating transactions prior to this date as belonging to a different unit. Our estimates are based on 87,381 repeat sales transactions, of which 22,476 occur after September 2000 when the border changes were made public. For the majority of the analysis, we keep only the first post–September 2000 transaction. This further drops our sample to 19,225 effective observations for this period. Of this sample, 1,849 residences were assigned a new secondary school, 1,941 a new elementary school, with only 78 experiencing changes in both elementary and secondary schools.

BCAA disaggregates Vancouver into thirty neighborhoods for the purpose of assessment. The goal of the allocation is to create a balanced workload for assessors while retaining a degree of neighborhood homogeneity. The BCAA boundaries do not perfectly match VSB school attendance zone boundaries and generally respect the split between the west and east sides of Vancouver (deviating only in the high-density downtown core, where many new high-rise condominium buildings have been constructed). The BCAA neighborhoods, created well before the school rezoning decision, provide an exogenous definition of neighborhoods to employ for measuring neighborhood price movements.

C. *Rezoning and Changes in School Quality*

In 75 areas, rezoning resulted in distinct combinations of old and new elementary schools. Among these, 20 experienced absolute changes in school quality of greater than

[9] Any units that transacted at least twice during 1996 to 2003 but not prior to 1996 are also included. Our coverage for a given time period gets sparse before 1996, but our goal is to identify price changes after 2000Q3, so this should not pose a problem for our analysis.

[10] Structure characteristics are limited to lot size, unit size, number of bedrooms, and unit age.

FIGURE 3.—VANCOUVER HOUSE SALES IN AREAS WITH CHANGES IN ELEMENTARY SCHOOL PERFORMANCE

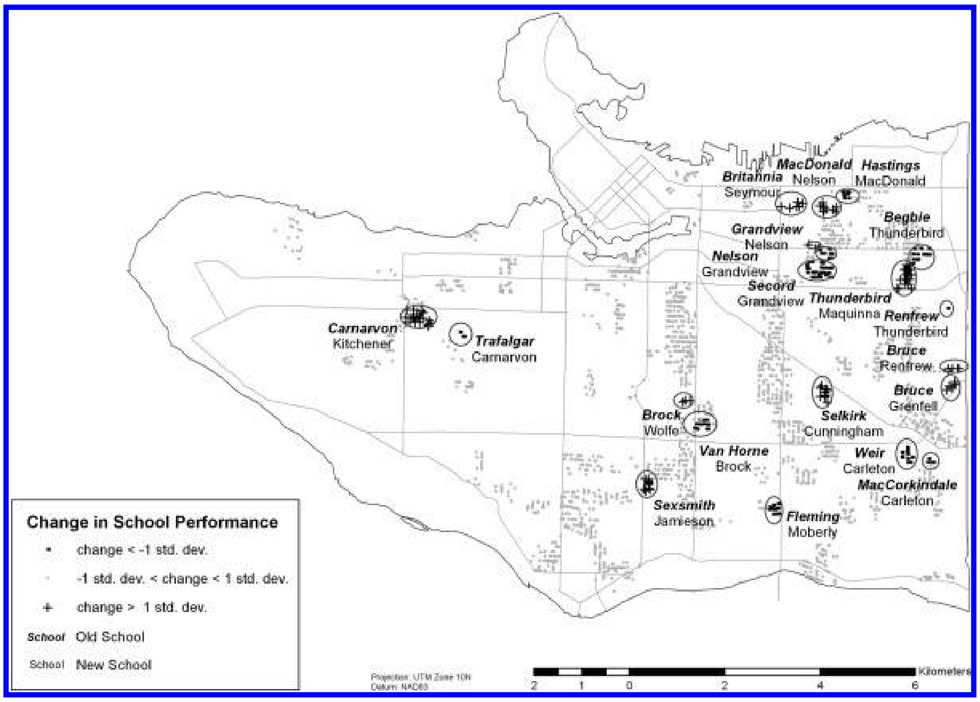
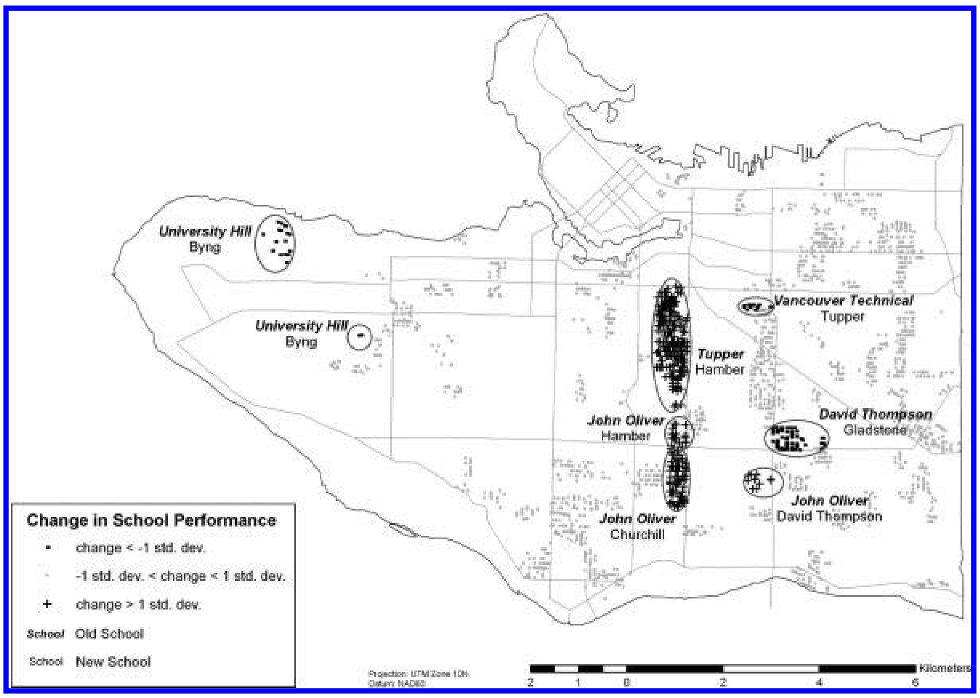


FIGURE 4.—VANCOUVER HOUSE SALES IN AREAS WITH CHANGES IN SECONDARY SCHOOL PERFORMANCE



1–standard-deviation in the initial distribution of school scores. Rezoning led to changes in secondary schools for 25 areas, with 8 of these areas experiencing changes of greater than 1–standard-deviation in the initial distribution of school scores. While we have many transactions, in practice our identification of school effects is based on a limited number of areas where the changes in school quality were significant.

Figures 3 and 4 identify the post-2000Q3 transactions that occurred in neighborhoods assigned new catchment areas for elementary and secondary schools, respectively. Transactions associated with school changes greater than 1–standard-deviation are denoted by a plus sign for positive changes and a minus sign for negative changes. We circle these transactions and list the old and new schools. For elementary schools, shown in figure 3, the transactions for which large changes occurred are focused around moves into and out of the low-scoring schools of Brock, Grandview, and MacDonald. Often the "better" school in a pair has a test score below the district mean. The exceptions are the movements from Brock to Wolfe or Carnarvon to Kitchener. As shown in figure 4, significant improvements in secondary school quality (more than 2 standard deviations in the initial school distribution) resulted from the reassignment from the two lowest-rated schools, Tupper and John Oliver, to two above-average schools, Hamber and Churchill.

Our empirical strategy is to measure the effect of the reassignment of residences from one school to another on changes in residential prices. Identification is based on postannouncement (September 2000) transactions of rezoned residences. We expect prices to be affected by the difference in the quality of the old and new school.

School quality itself may be influenced by rezoning through peer effects. For example, students in strong schools may be adversely affected by an influx of students from poorer schools. We do not think changing peer effects are important for our study for two reasons. First, the change in school population due to boundary changes was on average less than 10%. Second, our results are not sensitive to the timing of the measures of school performance. For example, as an alternative to using 1996–2000 Fraser Institute rankings to capture secondary school performance, we experimented with Fraser Institute rankings from 2001 to 2003. Here, the 2001–2003 rankings would reflect the new student composition generated by the boundary changes. School quality effects identified by differences in new and old school performance would reflect both the fact that the neighborhood was rezoned to a different school and any resulting changes in peer group effects brought about by rezoning. While estimated coefficients change a bit with different measures of school quality, they are not systematically stronger or weaker when we use the postannouncement performance as compared to preannouncement performance.

IV. Empirical Methodology

The hedonic approach to valuing school quality characterizes the value of house i as a function of its structure characteristics X, its amenities N in neighborhood n, school quality S for school attendance zone s. We can express residential prices in the standard semilog formulation as function of time-invariant structure and neighborhood characteristics, time-varying school characteristics, and an error term:

$$\ln(P_{inst}) = \beta X_i + \delta S_{st} + \gamma N_n + e_{inst}. \quad (1)$$

Unbiased estimation of δ, measuring the effect of school quality on residential prices, requires that the error term be uncorrelated with measures of school quality. We would expect better schools to be located in neighborhoods with nicer, well-maintained, high-quality houses and better neighborhood amenities, where typically all of the latter have at least some element that is not observed. Thus, estimates of δ are likely to be upwardly biased.

The repeat sales methodology first associated with Bailey, Muth, and Nourse (1963) can be used to eliminate time-invariant house and neighborhood characteristics and control for time-varying neighborhood characteristics. Letting $e_{inst} = \alpha_{nt} + u_{ist}$, between any two periods t and $t+j$, the change in underlying house prices is

$$\ln\left(\frac{P_{ins,t+j}}{P_{inst}}\right) = \alpha_{n,t+j} - \alpha_{nt} + \delta(S_{s,t+j} - S_{st}) + u_{is,t+j} - u_{ist}. \quad (2)$$

The estimation approach is to regress the log price ratio on neighborhood indicator variables taking on the value of 1 in period $t + j$ and –1 in period t. We will refer to this standard approach as the BMN method.

Due to the high degree of nonpersistence of temporal variation in school test scores, we identify δ based on residences that "move" from one school attendance area to another, so for a change of school s to school s', we have

$$\ln\left(\frac{P_{ins,t+j}}{P_{inst}}\right) = \alpha_{n,t+j} - \alpha_{nt} + \delta(S_{s'} - S_s) + u_{is,t+j} - u_{ist}. \quad (3)$$

The challenge is to differentiate between the effects of neighborhood price changes ($\Delta\alpha = \alpha_{n,t+j} - \alpha_{nt}$) from changes in schools ($\Delta S = S_{s'} - S_s$). We use repeat sales transactions for residences that share the same neighborhood as reassigned residences, but remain in the same school attendance area, to identify neighborhood price increases.

Our analysis is still potentially subject to the concern about excluded variable bias. In our case, it is not from price levels but in price changes: our coefficient estimate of the value of school quality would suffer from upward bias if the houses that transfer from the attendance zones of low-quality schools to those of higher-quality schools are located in parts of neighborhoods that are experiencing faster price appreciation than the neighborhood as a whole. To obviate this concern, we need our neighborhood price controls ($\Delta\alpha_n = \alpha_{n,t+j} - \alpha_{nt}$) to be as geographically disaggregated as possible. At the same time, to estimate δ, our neighborhoods have to be broader than the residential areas that changed schools.

FIGURE 5.—CITYWIDE: BAILEY-MUTH-NOURSE VERSUS FOURIER

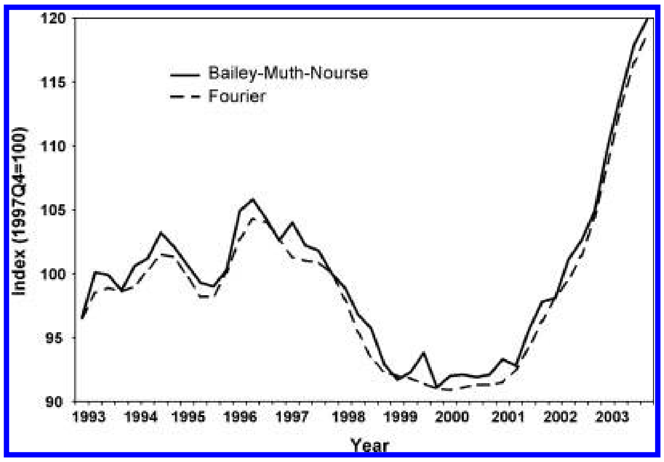
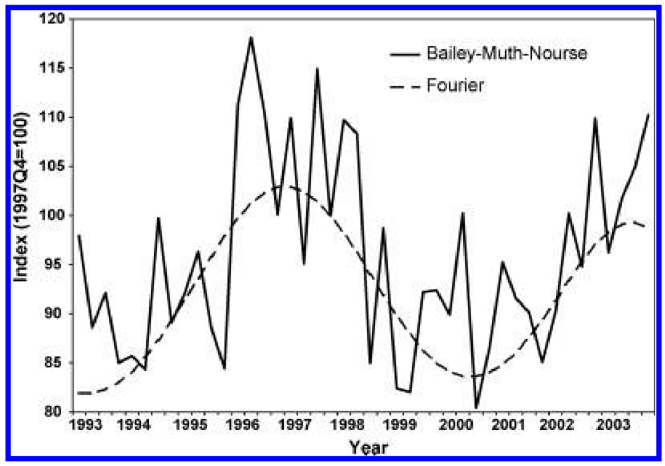


FIGURE 6.—SHAUGHNESSY NEIGHBORHOOD: BAILEY-MUTH-NOURSE VERSUS FOURIER



Measuring precise local price changes using a conventional BMN repeat sales approach is challenging. The methodology requires two transactions of the same house in the period of analysis, and there needs to be a transaction in every period. Further, housing is a heterogeneous good, where bargaining between the buyer and seller is the norm, such that in any period, observed transaction prices are distributed around the underlying market price. Repeat sales price indexes for small areas with limited transactions can be extremely noisy.[11] In our data, there are no paired transactions in at least one-quarter after the school boundary change in five of our thirty neighborhoods. To address this problem with the BMN methodology, we create neighborhood price indexes using a parametric smoothing technique to repeat sales data.

We use the Fourier expansion specification introduced by Gallant (1981) to create a series of smoothed neighborhood-level price indexes from the repeat sales data. This flexible parametric approach to index construction was introduced into the house price literature by McMillen and Dombrow (2001), and we rely heavily on their presentation of the technique. This specification is extremely flexible, yet because it is parametric, it can smooth over periods in the data when observations are sparse or nonexistent, making it ideal for price index construction at the neighborhood level, an application that McMillen (2003) used.

The Fourier expansion approach assumes an underlying temporal function where $P_{it} = g(T_t)$. For the Fourier transformation, this function $g(T)$ is transformed so that all values lie on the segment 0 to 2π: $z_t = 2\pi T_t/\max(T)$. The expansion of this function under the assumption that its parameters are time invariant is

$$g(T_t) = \tau_0 + \tau_1 z_t + \tau_2 z_t^2 + \sum\nolimits_q \lambda_q \sin(qz_t) + \rho_q \cos(qz_t)). \tag{4}$$

With equation (4) we can estimate equation (2) for the units that did not change school attendance areas as

$$\ln\left(\frac{P_{in,s,t+j}}{P_{in,s,t}}\right) = \tau_1(z_{t+j} - z_t) + \tau_2(z_{t+j}^2 - z_t^2) + \sum\nolimits_q \lambda_q\{\sin(qz_{t+j}) - \sin(qz_t)\} + \rho_q\{\cos(qz_{t+j}) - \cos(qz_t)\} + u_{isn,t+j} - u_{isn,t}. \tag{5}$$

We use OLS regressions on transaction prices to estimate these parameters. The lag length q is determined using the Schwartz information criterion and varies by neighborhoods.

Figures 5 and 6 show the difference between a standard BMN repeat sales index and one created using the Fourier smoothing technique. For the citywide data (figure 5), where the sample size is large, the difference is not meaningful. However, when we use more disaggregated data in figure 6 (defining the market at the BCAA neighborhood level for the neighborhood of Shaughnessy), the effect of smoothing becomes more apparent. The two series have the same general price pattern, but the noise manifest in the repeat sales index is filtered out with the Fourier approach.

Main Corridor. For secondary schools, the biggest mass of change occurs in a band along Main Street.[12] If prices in this corridor happen to be rising faster than those in the adjacent areas or in the larger neighborhoods for reasons other than school quality, the school price effect will be correlated with this omitted effect and be biased upward. To examine whether this is likely to be a concern, we compare a price index for units in the Main corridor, defined as the area 250 meters on either side of Main Street, with indexes for the west and east sides of Vancouver. Figure 7 shows these indexes for the 1990–2003 period. Over this period, residential prices rose fastest in the Main corridor,

[11] See Englund, Quigley, and Redfearn (1999) for a discussion of the challenges with repeat sales price indexes.

[12] Of the 442 transactions after September 2000 for houses whose catchment area changed and which improved their secondary school by at least two standard deviations, 227 occur within 250 meters of Main Street.

FIGURE 7.—MAIN CORRIDOR, EAST, AND WEST PRICE INDEXES

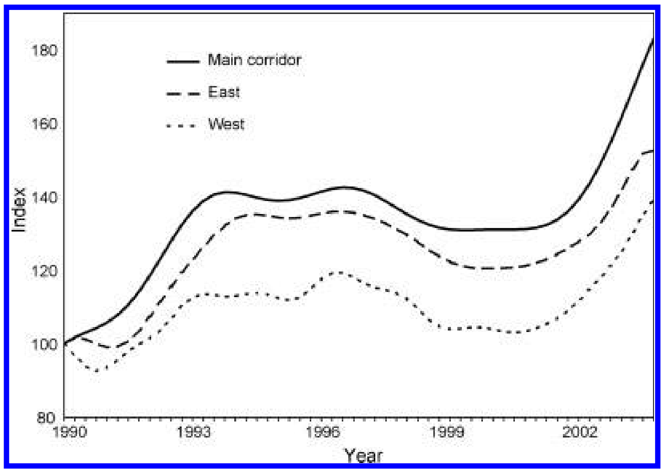
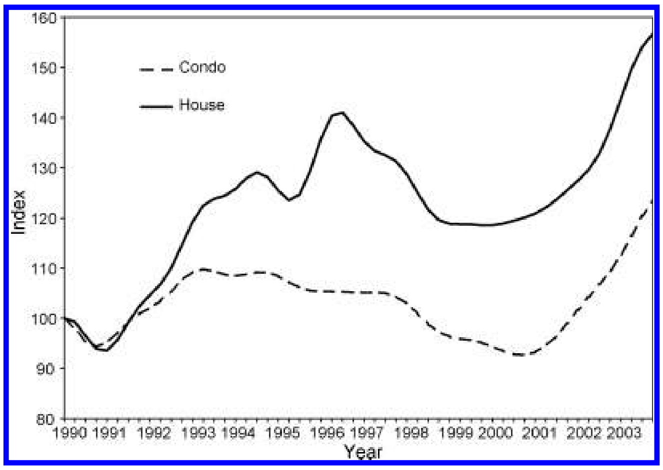


FIGURE 8.—HOUSE VERSUS CONDO PRICE INDEXES



with greater price increases on the east side than the west side of Vancouver. In the analysis, we employ disaggregated neighborhood price indexes to control for the differential price movements observed in figure 7.

Houses versus Condos. Our data set has four main types of properties: single-family dwellings, row houses, duplexes, and strata-title residences (principally condos). Rather than focus on single-family houses, as does much of the previous literature, we include all of these property types, since many have two or more bedrooms and are places where families reside in Vancouver. However, price changes may vary by type of residence. To control for this, we compute separate price indexes for two groups of properties: strata-title properties and others. For convenience, we will refer to strata-title properties as condos and nonstrata properties as houses. Figure 8 shows that houses appreciated much faster than condos over the 1990–2003 period but at varying relative rates, underscoring the importance of computing separate price indexes for each type of residence.

Repeat sales data enable us to employ a difference-in-difference approach to relate house price movements to the changes in school quality induced by rezoning. Price movements of residences that did not get assigned to new schools control for neighborhood price appreciation. The difference between the change in prices for these units and those that were rezoned is the treatment effect. The possibility of bias remains if the price appreciation of reassigned residences (the treatment group) differs from that experienced by residences that were not reassigned (the control group). Our approach mitigates this potential bias by computing highly disaggregated neighborhood price indexes for houses and condos.[13] In our final set of estimates, we also employ a third level of differencing by controlling for price trends in the areas subject to the rezoning.

V. Results

We begin by estimating school quality effects using a hedonic approach:

$$\ln(P_{inst}) = \alpha_{nt} + \beta X_i + \delta S_s + \gamma N_n + u_{ist}.$$

The vector of house characteristics, X_i, comprises number of bedrooms, linear and quadratic terms for unit and lot size, unit age, and years since the last major renovation or addition. We use neighborhood and quarterly fixed effects for α_{nt}. Elementary school quality is measured by the average score for the years 2000 to 2003 and normalized by the standard deviation of average scores across schools. Secondary school score is the 1996–2000 rating by the Fraser Institute normalized by the standard deviation of these ratings across schools. Our sample of 9,719 houses is the set that transacted after the announcement of boundary changes in September 2000, for which we have all housing characteristics.[14]

Table 1 lists results of the hedonic regressions. Column 1 does not employ neighborhood fixed effects, whereas each ensuing column shows results with increasingly geographically disaggregated fixed effects. Column 2 uses a dummy variable to capture the Vancouver west side and column 3 uses dummy variables for thirty BCAA neighborhoods. The last three columns employ school boundary fixed effects following Black (1999). We consider boundary areas that are 500, 350, and 250 meters from school catchment boundaries. Following Black, we confine the sample to houses within these boundary areas and exploit within-boundary variation in school performance.[15] Specifications 1 and 2

[13] Price indices based on repeat sales may be biased measures of overall price appreciation in a city due to noncomparability between units that transact and those that do not. Since our repeat sales analysis compares price movements of reassigned units to price movements of nonreassigned units, any bias associated with calculating prices indices with repeat sales data is netted out in our analysis.

[14] We exclude condos in the hedonic regressions. Characteristics such as lot size are not well defined for condos, and focusing on houses makes our results comparable to those in Black.

[15] Black defines boundary areas as .35 mile, .20 mile, and .50 mile from the boundary, roughly comparable to our areas.

TABLE 1.—HEDONIC REGRESSIONS

Specification		(1)	(2)	(3)	(4)	(5)	(6)
1	Elementary score	0.177***	0.044***	0.021***	0.013***	0.011**	0.007*
		(0.022)	(0.012)	(0.006)	(0.004)	(0.004)	(0.004)
	Observations	9,719	9,719	9,719	9,309	8,367	6,892
	R^2	0.757	0.829	0.851	0.858	0.855	0.854
2	Secondary score	0.194***	0.044***	0.023***	0.040***	0.029***	0.013**
		(0.035)	(0.012)	(0.008)	(0.013)	(0.009)	(0.005)
	Observations	9,719	9,719	9,719	6,585	4,977	3,617
	R^2	0.772	0.829	0.851	0.857	0.859	0.860
3	Elementary score	0.102***	0.038***	0.018***			
		(0.016)	(0.011)	(0.006)			
	Secondary Score	0.136***	0.036***	0.020**			
		(0.016)	(0.010)	(0.008)			
	Observations	9,719	9,719	9,719			
	R^2	0.792	0.831	0.851			
Fixed effects		None	East-West	BCAA	Boundary 500 m	Boundary 350 m	Boundary 250 m

*,**,*** denote 10%, 5%, and 1% level of significance. Standard errors allow for clustering (based on school for specifications 1 and 2 and unique elementary-secondary combination for specification 3). Property characteristics include linear and quadratic terms for unit area and lot size, as well as linear terms for bedrooms, unit age, and years since last major renovation. We include quarterly time dummies.

estimate elementary scores and secondary scores in separate regressions. The Black-type boundary fixed effects are defined by distances from elementary school boundaries or distances from secondary school boundaries; consequently, they are not unique to a house and should not be incorporated into a single regression. For specifications 1 and 2, since the error terms are likely to be correlated for residences in neighborhoods sharing a common school, the standard errors allow for clustering at the school level. Specification 3 estimates coefficients for secondary and elementary scores simultaneously. In these regressions, clustering is based on unique elementary-secondary neighborhoods based on pre-rezoning catchment areas.

Table 1 reveals that after controlling for house characteristics and neighborhood effects, school scores are positively and significantly associated with housing prices.[16] Since the scores are normalized by the standard deviation, the coefficients are interpreted as the percentage change in house value associated with a 1–standard-deviation increase in the rating of a school. Column 1, with no neighborhood fixed effects, shows very large coefficients, reflecting bias due to omitted neighborhood effects. As we employ more geographically precise fixed effects, the coefficients fall but remain statistically different from 0. The coefficients for elementary test scores are somewhat smaller than those reported by Black (1999). For the narrowest boundary region, a 1–standard-deviation increase in performance is associated with a 0.7% increase in residential prices, as compared to 2.1% in her study. The effect of secondary scores tends to be higher than that of elementary scores, especially in the boundary regressions, and the individual coefficients are lower when the effects of elementary and secondary school scores are estimated jointly. The concern with the hedonic approach is that they suffer from bias because of omitted neighborhood and household characteristics, which is consistent with coefficient estimates falling as we define neighborhoods more precisely.

[16] Unreported coefficients on house characteristics have the expected signs.

We now turn to our repeat sales specification that allows us to relate changes in a residence's value to changes in school quality due to rezoning:

$$\ln\left(\frac{P_{ins,t+j}}{P_{inst}}\right) = \alpha_{n,t+j} - \alpha_{n,t} + \delta(S_{s'} - S_s) + u_{is,t+j} - u_{ist}.$$

Recall the key issue is differentiating between the evolution in neighborhood prices ($\Delta\alpha = \alpha_{n,t+j} - \alpha_{nt}$) from the effect of changes in school quality ($\Delta S = S_{s'} - S_s$). Our procedure is to compute price indexes at different levels of disaggregation to capture changes in the level of house prices ($\Delta\alpha$) and then use the sample of transactions that straddle the rezoning announcement to estimate the effects of changes in school scores. The house and condo price indexes that measure $\Delta\alpha$ are calculated using only transactions of residences that do not change schools, so the effect of $\Delta\alpha$ is orthogonal to ΔS. To be precise, we compute the indexes using price information from all transactions before the September 2000 announcement of boundary changes and price information on units that were not reassigned for transactions subsequent to the announcement. The key variable of interest, the change in school score (ΔS), is nonzero only in the case where a house is reassigned. We add quarterly dummies to account for any discrepancies between average house price changes in a quarter and the price index that are not explained by school changes. Finally, the standard errors are adjusted to allow for correlations across errors for residences that share common secondary and elementary schools before rezoning.

Table 2 reports the coefficients on changes in school scores as well as the price index for different geographic disaggregation of the price indexes. Column 1 employs a citywide index. The next two columns use indexes based on the catchment areas for the eighteen secondary schools, with column 2 based on the pre-rezoning catchment areas

TABLE 2.—SCHOOL BOUNDARY CHANGE (REPEAT SALES), DIFFERENT INDEXES

	(1) Citywide	(2) Old Secondary	(3) New Secondary	(4) BCAA	(5) W-E-Main
Full Sample					
Price index	0.986***	0.980***	0.978***	0.983***	0.979***
	(0.007)	(0.005)	(0.005)	(0.005)	(0.006)
Elementary score	−0.024*	−0.013*	−0.013*	−0.006	−0.024**
	(0.013)	(0.007)	(0.007)	(0.007)	(0.012)
Secondary score	0.021**	0.006	0.042***	0.013	0.015
	(0.010)	(0.006)	(0.011)	(0.008)	(0.010)
Observations	19,225	19,082	19,076	18,902	19,225
R^2	0.785	0.805	0.803	0.811	0.794
No tails					
Price index	0.994***	0.990***	0.988***	0.993***	0.989***
	(0.008)	(0.005)	(0.005)	(0.004)	(0.006)
Elementary score	−0.021*	−0.009	−0.009	−0.002	−0.020*
	(0.012)	(0.006)	(0.006)	(0.007)	(0.011)
Secondary score	0.024***	0.009**	0.045***	0.016***	0.018*
	(0.008)	(0.005)	(0.009)	(0.006)	(0.010)
Observations	18,522	18,448	18,469	18,522	18,522
R^2	0.834	0.855	0.853	0.861	0.842

*,**,*** denote 10%, 5%, and 1% level of significance. Standard errors allow for clustering within each unique elementary-secondary neighborhood based on pre-rezoning catchment areas. "No tails" sample excludes 1% tails from regression of house price change on price index. Quarterly dummies included.

(old secondary) and column 3 based on the post-rezoning catchment areas (new secondary). Column 4 reflects results when indexes are created for thirty BCAA neighborhoods, and column 5 indexes the west and east sides of Vancouver and the Main corridor as portrayed in figure 7. The number of observations decreases slightly when we employ disaggregated price indexes due to inadequate numbers of condo transactions in a few neighborhoods.

House price regressions often have unusual outliers because of unobserved characteristics or non–arm's-length or bundled transactions. We report results for the full sample as well as a reduced sample where we eliminate the 1% tails from a regression of log price changes on the log BCAA index change. Trimming these outliers improves the fit and slightly reduces the standard errors of the coefficients.

Table 2 reveals positive effects for changes in secondary school performance due to rezoning and negative effects for changes in elementary school performance. The negative elementary school effect is perverse, although it generally becomes statistically insignificant once we eliminate the 1% tails of the distribution and use disaggregated price indexes. The failure to find positive and significant effects for elementary school quality is at odds with previous findings.

The secondary school effect tends to be significant, especially in the no-tails regressions. The magnitude of the estimated effects indicates that a 1–standard-deviation change in secondary school performance is typically associated with a 1 to 2 percentage point change in house price appreciation. We observe a very large effect when we use the new school catchment areas as neighborhoods for computing price indexes (column 3). Recall from figure 7 that the west side of Vancouver did not experience the price appreciation observed in the Main corridor and the east side. This specification attaches the lower price appreciation of the west side to the properties in the Main corridor that experienced very large increases in secondary school performance due to the rezoning.[17]

Our preferred specification is the one with the BCAA price index that eliminates the extreme observations (results presented in column 4 for the lower panel). It employs the most disaggregated price index, and the results above indicate it provides the best fit to the data. With this specification, a 1–standard-deviation increase in school performance is associated with a 1.6% increase in price. In the Main corridor, areas rezoned Tupper-to-Hamber, Tupper-to-Churchill, and Oliver-to-Churchill realized changes in school quality exceeding 2 standard deviations (2.04, 2.18, and 2.37, respectively), indicating rezoning resulting in 3.5% house appreciation for these properties.

Up to now we have considered heterogeneity in terms of geography. However, residential submarkets may break down by unit type as well. In table 3 we split residences into those that are most likely to house families and those that are not. We consider four ways to divide the properties based on whether they have two or more bedrooms, have three or more bedrooms, are in the top half in terms of unit area (greater than 1,332 square feet), and have a lot size exceeding 2,000 square feet. We report results using the BCAA prices indexes with extreme observations eliminated. The sample sizes in these regressions are reduced due to incomplete information on unit characteristics.

Table 3 reveals that the coefficients on school quality for family-oriented and other units for each specification are

[17] We note that the coefficient on the price index tends to be very close to 1 but is often significantly smaller than 1. This is a consequence of using the Fourier transformation and disaggregated price indexes (even the citywide index disaggregates by house and condo). The procedure imposes a parametric form, which can result in a small amount of specification bias with regard to the actual price movements in the sample. Eliminating the extreme observations moves the coefficient of the price index closer to 1. Constraining the coefficient on the price index to be 1 does not affect the results.

TABLE 3.—SCHOOL BOUNDARY CHANGE (REPEAT SALES)
EFFECTS FOR FAMILY VERSUS NON-FAMILY-ORIENTED UNITS

Definition of Family Oriented	(1) 2 or More Bedrooms	(2) 3 or More Bedrooms	(3) Unit Area over 1,332 feet	(4) Lot Size over 2,000 Feet
Price index	0.992***	0.992***	0.992***	0.992***
	(0.004)	(0.004)	(0.004)	(0.005)
Elementary score	−0.003	−0.005	−0.004	−0.008
Family oriented	(0.007)	(0.007)	(0.008)	(0.006)
Other	−0.008	0.002	−0.002	0.014
	(0.017)	(0.011)	(0.010)	(0.019)
Secondary score	0.015**	0.012	0.015**	0.012*
Family oriented	(0.007)	(0.008)	(0.007)	(0.007)
Other	0.011	0.020***	0.014**	0.021***
	(0.017)	(0.005)	(0.006)	(0.005)
Observations	17,351	17,351	17,344	17,351
R^2	0.860	0.860	0.860	0.860

*,**,*** denote 10%, 5%, and 1% level of significance. Standard errors allow for clustering within each unique elementary-secondary neighborhood based on pre-rezoning catchment areas. Family versus nonfamily based on the criteria indicated in the top row. One percent tails from regression of house price change on price index are excluded. Quarterly dummies included.

generally within 1–standard-deviation of each other. The difference is greatest and of the "reverse" sign for the lot area specification (column 4). The results are sensitive to whether we consider the 4,718 units with two bedrooms to be family oriented. When we include them as family oriented, the coefficient for secondary school change on family-oriented units is 0.15 and is significantly different from 0 at the 5% level, whereas that for non-family-oriented units is lower and insignificantly different from 0 (column 1). However, when we consider two-bedroom units to be non-family-oriented units, the estimate of these units rises to .020 and is highly significant (column 2).

The prices on family-oriented units are much higher than those on other units. For example, for the sample used in the column 1 regression in table 3, the median price of a unit with two or more bedrooms was $320,000, whereas it is $147,900 for fewer than two-bedroom units (mostly condos). The 1.5% increase in the former resulting from a 1–standard-deviation increase in secondary school quality is $4,800. The smaller units would have to increase by 3.2%, well above the point estimate of 1.1% in column 1, to have a comparable level increase in value. Thus, the estimated change in the level of house prices resulting from an increase in secondary school score for the median two or more bedroom units is more than double that for smaller units.

In our final test of heterogeneity, we allow differences in school quality effects by house quality. We split the sample into quartiles based on the price per square foot of housing. We allow different effects of elementary and secondary school quality for each quartile. Given a particular preference for unit size, high-income households will purchase higher-quality, more expensive units. Our motivation for this test is that education is a normal good, and purchasers of high-end properties have higher incomes and thus should exhibit a greater willingness to pay for good schooling.

The results in table 4 are quite striking. Uniformly the coefficients on the change in school quality rise with the price per square foot quartiles for both elementary and secondary performance. Moreover, we see that the effects of changes in secondary school quality are confined to units above the median price per square foot. A 1–standard-deviation increase in secondary school quality increased top-quality residential prices by 3.8% and those in the second highest quartile by 2.5%. For the top-quartile residences, the coefficient on elementary school quality is positive and 1.43 standard deviations above 0.

TABLE 4.—SCHOOL BOUNDARY CHANGE (REPEAT SALES)
EFFECTS BY HOUSE PRICE PER SQUARE FOOT QUARTILE

Price per Square Foot	(1) Secondary Score	(2) Elementary Score
Bottom quartile	−0.004	−0.012
	(0.011)	(0.010)
2nd quartile	0.003	−0.009
	(0.011)	(0.013)
3rd quartile	0.025*	−0.002
	(0.014)	(0.013)
Top quartile	0.038***	0.029
	(0.010)	(0.020)

*,**,*** denote 10%, 5%, and 1% level of significance. Standard errors allow for clustering within each unique elementary-secondary neighborhood based on pre-rezoning catchment areas. One percent tails from regression of house price change on price index are excluded. There are 17,344 observations, the R^2 is 0.860, and the coefficient on the BCAA price index is 0.992. Quarterly dummies are included.

Our sample includes the first transaction following the announcement of boundary changes and excludes subsequent ones. If prices, however, respond slowly to new information, subsequent transactions may also reflect changes in school quality. There are 2,517 transactions that occurred subsequent to the first post-2000Q3 transaction, of which 242 and 287 correspond to residences with new secondary and elementary catchment areas. To test for information lags, we reestimate equation (3) using this sample.

Table 5 reveals that the specification fits quite poorly to these transactions: the estimated coefficients on the index are close to 0 and the R^2s are very low. The coefficients on the quarter dummy variables (not reported in the table) are about .2, indicating that these units appreciated much faster than the index predicts. The period over which these residences were held was relatively low (a median of 421 days) and the high price increase suggests that many of them were renovated and resold. Interestingly, the estimated school

TABLE 5.—SCHOOL BOUNDARY CHANGE (REPEAT SALES), INFORMATION LAGS

	(1) City wide	(2) Old Sec.	(3) New Sec.	(4) BCAA	(5) W-E-Main
Price index	−0.066	0.182*	0.182*	0.241**	−0.042
	(0.159)	(0.098)	(0.094)	(0.115)	(0.137)
Elementary score	−0.029*	−0.028*	−0.028*	−0.027*	−0.028*
	(0.015)	(0.015)	(0.015)	(0.016)	(0.015)
Secondary score	0.013	0.016	0.016	0.013	0.013
	(0.019)	(0.020)	(0.019)	(0.018)	(0.019)
Observations	2,517	2,502	2,506	2,517	2,517
R^2	0.023	0.026	0.026	0.028	0.023

*,**,*** denote 10%, 5%, and 1% level of significance. Standard errors allow for clustering within each unique elementary-secondary neighborhood based on pre-rezoning catchment areas. No-tails sample excludes 1% tails from regression of house price change on price index. Quarterly dummies included.

effects are similar to those we estimated in table 1 for first transactions (subsequent to the announcement). If one were to focus solely on the positive secondary scores, an interpretation is slow adjustment to the information. However, the perverse negative coefficient on elementary scores persists with the new sample and cannot be understood in this context of information lags. They are, however, consistent with the presence of persistent price trends in areas that were rezoned to new elementary schools.

The results in table 5 raise the concern that we are not fully capturing price movements in the areas rezoned to better schools. Specifically, even with narrowly defined neighborhood price indexes, $S_{s'} - S_s$ may still be positively correlated with $u_{is,t+j} - u_{ist}$. To distinguish the treatment effect of rezoning from price trends, we add 9,209 pairs of repeat-sales transactions where the second sale occurred in 1998 or 1999.[18] Since these transactions occurred prior to any public discussion of the boundary change, they will be unaffected by the subsequent rezoning.[19] Their inclusion allows us to perform two tests of whether unobserved price trends explain our results. First, we add fixed effects corresponding to each old school–new school pair (147 areas for elementary schools and 43 for secondary schools) and fit the following specification:

$$\ln\left(\frac{P_{ins,t+j}}{P_{inst}}\right) = \alpha_{n,t+j} - \alpha_{n,t} + FE_{s,s'} + \gamma(S_{s'} - S_s) + u_{is,t+j} - u_{ist}. \quad (6)$$

The fixed effects will capture average price changes (relative to the neighborhood price index) in these narrowly defined areas in 1998–1999 and 2000Q3–2003. As before, $S_{s'} - S_s$ is nonzero only for post-2000Q3 transactions for residences that were rezoned. Thus the coefficient γ measures the marginal effect of school quality changes on house price appreciation after controlling for both the average price appreciation in the rezoned neighborhood (effectively over 1998 to 2003) and the rate of house price appreciation in the broader neighborhood.

In the second exercise, we estimate

$$\ln\left(\frac{P_{ins,t+j}}{P_{inst}}\right) = \alpha_{n,t+j} - \alpha_{n,t} + \delta(S_{s'} - S_s) + \psi D_{2000Q3+}(S_{s'} - S_s) + u_{is,t+j} - u_{ist}, \quad (7)$$

where $D_{2000Q3+}$ takes on a value of 1 for transactions that occurred subsequent to the announcement.[20] Changes in school scores ($S_{s'} - S_s$) are applied to both 1998–1999 and post-2000Q3 residential transactions. School quality effects that are common to both the 1998–1999 (placebo) period and the postannouncement (treatment) period are captured by δ, whereas ψ measures the differential effect for the treatment period. If school quality changes are not correlated with price movement in these neighborhoods, δ should be 0. Thus, the estimate δ serves as a falsification test. School quality changes during the treatment period are measured as $\delta + \psi$.

The results portrayed in table 6 suggest the effects of school boundary changes on house prices that we identify for the post-2000Q3 transactions are largely a consequence of longer-run price trends in rezoned neighborhoods. The top panel shows results when we include the fixed effects for neighborhoods defined as each unique combination of old and new school. None of the estimated coefficients on elementary and secondary school quality change are significantly different from 0. The estimate of secondary school quality using the preferred BCAA price index is 0.007, approximately 45% of its value in the regression reported in table 2. We also observe that the negative estimates of elementary school quality displayed in table 2 are essentially eliminated when we control for unobserved price trends in rezoned areas.

In the lower panel, the baseline school score estimates, δ, reflecting common effects for the placebo and treatment periods, are similar to what we observed in table 2. The differential school effects (ψ) for the treatment period tend to be small and positive but insignificantly different from 0.

[18] We thank a referee for suggesting we employ pre-announcement information for falsification testing.

[19] The previous sample used observations starting in the fourth quarter of 2000. We do not use the first three quarters of 2000 out of concern that there might have been rumors of pending boundary changes.

[20] As before, we remove the 1% tails. To comparably treat the post-2000Q3 and 1998–1999 transactions, we recompute the price index excluding the 1998–1999 transactions in areas that were to experience school rezoning.

TABLE 6.—SCHOOL BOUNDARY CHANGE (REPEAT SALES), FALSIFICATION

	(1) City wide	(2) Old Secondary	(3) New Secondary	(4) BCAA	(5) W-E-Main
Fixed effects					
Price index	0.985***	0.978***	0.977***	0.980***	0.984***
	(0.007)	(0.005)	(0.005)	(0.005)	(0.005)
Elementary score (γ_e)	−0.001	0.003	0.004	−0.002	−0.003
	(0.012)	(0.010)	(0.010)	(0.009)	(0.010)
Secondary score (γ_s)	0.008	0.007	0.005	0.007	−0.003
	(0.009)	(0.008)	(0.009)	(0.006)	(0.008)
Observations	26,629	26,567	26,593	26,629	26,629
R^2	0.838	0.847	0.846	0.852	0.844
Falsification					
Price index	0.986***	0.983***	0.982***	0.984***	0.986***
	(0.006)	(0.005)	(0.005)	(0.004)	(0.005)
Elementary score baseline (δ)	−0.018*	−0.014*	−0.013	−0.010	−0.016*
	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)
Elementary score post-2003Q3 (ψ)	−0.001	0.004	0.003	0.001	0.000
	(0.012)	(0.010)	(0.010)	(0.008)	(0.009)
Secondary score baseline (δ)	0.021	0.002	0.043***	0.013	0.019
	(0.015)	(0.012)	(0.016)	(0.013)	(0.015)
Secondary score post-2003Q3 (ψ)	0.006	0.007	0.004	0.007	−0.003
	(0.009)	(0.008)	(0.009)	(0.006)	(0.007)
Observations	26,629	26,567	26,593	26,629	26,629
R^2	0.824	0.842	0.841	0.848	0.832

*,**,*** denote 10%, 5%, and 1% level of significance. Standard errors allow clustering within each unique elementary-secondary neighborhood based on pre-rezoning catchment areas. Quarterly dummies included.

TABLE 7.—EFFECTS BY HOUSE PRICE PER SQUARE FOOT QUARTILE, FALSIFICATION

	Secondary Score		Elementary Score	
Price per Square Foot	Baseline (δ)	Post-2000Q3 (ψ)	Baseline (δ)	Post-2000Q3 (ψ)
Bottom quartile	0.013	−0.018	−0.012	0.003
	(0.026)	(0.025)	(0.013)	(0.014)
2nd quartile	−0.011	0.010	−0.021	0.006
	(0.009)	(0.012)	(0.021)	(0.022)
3rd quartile	0.025	0.008	0.024	−0.032
	(0.018)	(0.015)	(0.021)	(0.022)
Top quartile	0.030***	0.019**	−0.041	0.054**
	(0.009)	(0.008)	(0.028)	(0.023)

*,**,*** denote 10%, 5%, and 1% level of significance. Standard errors allow clustering within each unique elementary-secondary neighborhood based on pre-rezoning catchment areas. One percent tails from regression of house price change on price index are excluded. There are 24,809 observations, the R^2 is 0.850, and the coefficient on the BCAA price index is 0.982. Quarterly dummies included.

They are very similar to the estimates in the fixed effects specification. Overall, the results in table 6 indicate that unobserved price trends in rezoned neighborhoods were a source of omitted variable bias in our previous specifications.

Table 4 indicates that price changes for high-value residences responded most strongly to changes in school quality from rezoning. We interpreted this result as supporting the proposition that the boundary changes caused significant price effects and that the marginal preference for school quality rises with income or wealth. To provide a falsification test of these results, we turn to the sample used in the previous exercise that includes the 1998–1999 transactions and reestimate the specification, allowing school effects for post-2000Q3 transactions to have additional effects to those for the full sample. The results are shown in table 7.

The baseline secondary score estimates displayed in the first column measure common effects of changes in school quality for 1998–1999 and post-2000Q3 transactions. We observe that school scores exert the largest effects on residences in the top two quartiles, with the estimate for the top-quartile residences significantly different from 0. The differential effects of secondary score changes for treatment transactions, shown in the second column, are positive for the top three quartiles. For the top-quartile residences in terms of value, the differential effect is 0.19 and significantly different from 0 at the 5% level. The baseline estimates for elementary score (column 3) exhibit no pattern across the quartiles, and none are significant. The last column reveals that the estimate for top-quartile residences in the treatment period is significantly higher than the baseline. However, the total effect ($\delta + \psi$) of elementary scores for top-quartile residences is 0.013 and insignificantly different from 0.

These falsification exercises suggest that except for high-value residences, boundary changes had very little effect on residential values in Vancouver. The positive secondary and negative elementary score estimates for our earlier repeat sales specifications shown in table 2 are largely attributable to neighborhood price trends that predate the boundary changes. One possible explanation for rising prices and coincident boundary changes is reverse causality: areas that were becoming more desirable were becoming denser, leading to overcrowded catchment areas. This may be the case for the Main corridor, where gentrification spread from the Vancouver west side and into neighborhoods zoned for low-performing Tupper and Oliver.[21] For there to be a positive correlation between schools scores and neighborhood prices, however, rezoning had to result in an improvement in secondary schools. This did occur in this case, but it seems coincidental: overcrowding could have been alleviated by rezoning some Tupper and Churchill residences to other weak schools in East Vancouver. Moreover, positive correlation due to reverse causality certainly is not apparent in the results for elementary schools.

While acknowledging general insignificance of the estimates, we think it is instructive to compare our results to those in the literature to assess their economic plausibility. According to column 4 of table 6, when we use the BCAA index to control for pre-announcement neighborhood trends, the estimated effect of a 1–standard-deviation increase in secondary schools quality is associated with a 0.7% increase in prices. Table 7 shows that the residences with the highest value realized a 1.9% increase beyond the baseline control. In the Tupper-to-Hamber, Tupper-to-Churchill, and Oliver-to-Churchill areas, the change in school quality exceeds 2 standard deviations. If we take our estimates literally, the effect of rezoning in the Main corridor increased prices there between 1.5% and 4.0%. There are 365 residences that transacted after the boundary change announcement in these Main corridor areas, with a median price of $336,000. Among these, 93 transaction units were in the top quartile of value with a median price of $390,000. According to our point estimates, improved secondary school quality led to a level change in prices in this neighborhood of as little as $5,000 for the median unit and as much as $16,000 for high-value units.

Relatively small effects are not surprising given previous results in the literature. Black (1999) estimates that a 1–standard-deviation increase in elementary school test score is associated with a 1.8% to 2.1% increase in house prices. Bayer et al. (2007) also look at elementary school performance and find that after controlling for sociodemographic characteristics and boundary area fixed effects, a 1–standard-deviation increase raises average monthly user cost of housing by 1.8%, which corresponds to about $4,500 in house value in 1990. Our estimates of a 1–standard-deviation change in secondary and elementary school quality on residential price appreciation are smaller than those in Bayer et al. (2007) and imprecisely estimated. Smaller effects are expected considering that the repeat sales methodology eliminates sources of positive bias in the Bayer et al. study such as unobserved house and neighborhood characteristics (for example, granite countertops for residences on the higher-test-score side of a school boundary).

One explanation for the small effects that we find is that the boundaries in Vancouver were not absolutely binding and parents could apply cross-boundary to better schools. As we detail in the appendix, no records are kept on success rates for cross-boundary applications. Interviews we conducted with school administrators suggest, however, that it was very difficult to enter schools as a regular cross-boundary applicant. Although children do cross boundaries, there are clearly no guarantees of success.

Another possible explanation for the weak effects is that they reflect mean preferences across heterogeneous individuals and that many households, those without school-aged children, do not value school quality. Bayer et al. (2007) establish that "the hedonic price regression coefficients are indeed very close to mean preferences for housing and neighborhood attributes that vary more or less continuously throughout the metropolitan area, including school quality and neighborhood income and education" (p. 592). Thus, we can interpret our estimates as representing the mean preference among a heterogeneous population, some of whom care a great deal about public schools and some of whom do not. Using provincial and metropolitan area census data, we calculate that in Vancouver, no more than 33% of households had school-age children at home.[22] If the 67% of households without school-aged children place no value on public schools, then the average valuation of households that do value public schools will be three times the mean preferences observed in a hedonic regression. However, Hilber and Mayer (2004) provide evidence that even households without children will support improvements in education as a local amenity if they believe the benefits can be capitalized in house values. If households without children are willing to pay half the premium that households with children pay to purchase homes in neighborhoods with good public schools, then the average valuation of public schools for households with children is 50% higher than the mean preferences estimated in a hedonic regression.

VII. Conclusion

The rezoning of public schools in Vancouver in 2000 provides a natural experiment to investigate the valuation of school quality as capitalized into housing prices. Since the rezoning moved individual residences into different school catchment areas, we are able to use substantial cross-school variation in school quality while simultaneously employing repeat sales methods to control for unobserved characteristics of homes and neighborhoods. To control for time-varying changes in neighborhoods, we calculate price indices for narrow geographic areas and separate indexes for houses and condos. We also use transaction

[21] We should note, however, that increases in density may not lead to school overcrowding. In Vancouver, higher density has come overwhelmingly from the building of condominium buildings, which are less likely to include households with school-age children.

[22] Thirty-nine percent of households in Vancouver have children under age 25 living at home. We use provincial information that 85% of the households with children under the age of 25 living at home have children under the age of 18 at home to arrive at the 33% figure ($.39 \times .85 = .33$).

data that occurred prior to the boundary change announcement to control for price trends occurring in rezoned neighborhoods.

The cross-sectional hedonic regressions reveal large and significant effects of school quality on residential prices. When we employ repeat sales analysis, the effects remain for secondary schools. When we control for price trends in neighborhoods subject to the rezoning, however, school quality effects largely disappear. The prices of the top quartile of residences (in terms of price per square foot of living area) are the only units that appear to be influenced by changes in school quality. This result is consistent with the proposition that these residences are purchased by high-income households with strong preferences for good schools.

Our results underscore the inherent difficulties of identifying effects of school quality. Employing only cross-sectional information will lead to bias unless the researcher is able to control for every feature of neighborhoods and residences that may be positively correlated with school scores. The repeat sales approach greatly eases the information demands by eliminating time-invariant unobservable influences but must contend with other estimation issues. First, except in unique situations such as this one, where the rezoning permits identification based on cross-sectional school performance variation, estimation may be confounded by noisy within-school variation in school performance. Second, although a large sample of house transactions enables computation of very disaggregated neighborhood price indices to control for time-varying neighborhood price effects, school quality changes may be correlated with unobserved price trends in the very same set of residences that are subject to the rezoning. Our results highlight the methodological challenges in obtaining unbiased estimates of the value of any local amenity using house prices.

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APPENDIX

Options to Local Public Schools in Vancouver

Options to local public schools in Vancouver include French immersion, private schools, and cross-boundary admission. There are eight early French immersion elementary schools (starting in kindergarten), two French immersion elementary schools late (starting in sixth grade), and three secondary schools offering French immersion. In 2004, approximately 9% of grade 4 students in public schools attended French immersion. Students must apply for these schools. Demand for the program is growing, and in 2005 nearly one-third of those who applied were turned away for lack of space. Perhaps surprisingly, applications for French immersion come disproportionately from families residing on the west side of Vancouver, where the higher-scoring regular schools are located.

Of those taking the 2004 FSA exams, 17% were from students who attend independent schools.[23] However, most of these students (75%) attend Jewish, Protestant, Roman Catholic, or Sikh parochial schools. There are a small number of highly reputed private schools in Vancouver. A boys' private school and three girls' private schools all scored a perfect 10 out of 10 in the Fraser Institute secondary school ratings over the past five years. Annual tuition at these four schools ranges from $12,000 to $16,000. Most parochial school students attend Catholic schools. Overall, tuition at the parochial schools runs from $4,000 to $8,500, with Catholic schools being less expensive. The private school tuitions provide a high upper bound on the value of locating near a top public school. Assuming the benefit of a good local public school associated with not having to pay for private education is $10,000 per year per child and that it accrues forever and a 5% discount rate, then the upper bound is $200,000 per child.

A cheaper option is to apply for cross-boundary admission to a good public school. Unfortunately, the VSB does not keep records on the number of applications and the success rate of applicants. Individual schools may take applications in the spring but apparently discard the lists once

[23] The share of students in the public system is likely to be higher as some English as a Second Language and special needs students are exempted from the FSA. These students are primarily in the public system where some resources exist to provide them with assistance.

the school year begins. We conducted interviews with a few areas that we thought, being good schools near to areas with poor schools, would be likely targets for cross-boundary students. Hamber and Churchill are west side secondary schools near the east side of Vancouver. The discussion was complicated by the fact that secondary schools have special programs in certain fields (for example, science, music, drama) where students apply cross boundary. Our focus is on cross-boundary applications into the regular program. Both schools suggested the success rate for entering cross-boundary was very low. Indeed, John Hunter, vice principal of Sir Winston Churchill Secondary School, states in an e-mail, "There are many cross boundary applications received at Churchill, and few get placed. We have enough students in our catchment area, and more keep coming into the area throughout the year, that few regular cross boundary applications are accepted. If they are accepted it is to keep family siblings together. . . . Bottom line: it is very difficult to get into Churchill unless the student is resident in our catchment. . . . I would presume that if you asked all the schools west of Main St. that you would have similar answers: the schools generally have just enough room for the students in their catchment area, and there are few cross boundary applications accepted." We also contacted Nelson and Wolfe Elementary Schools. Nelson said they rarely take cross-boundary students, whereas Wolfe said many applications are rejected.

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