Centre for Urban Economics and Real Estate

Working Paper
2004 – 01

School Quality and Residential Values: Evidence from Vancouver Zoning

John Ries
University of British Columbia

and

Tsur Somerville
University of British Columbia

December 20, 2004

Centre for Urban Economics and Real Estate
Sauder School of Business
University of British Columbia
2053 Main Mall
Vancouver, BC V6T 1Z2
Tel : 604 822 8399 or e-mail : cuer@sauder.ubc.ca
Web: http://realestatecentre.ubc.ca/

School Quality and Residential Property Values: Evidence from Vancouver Rezoning[1]

John Ries[†] and Tsur Somerville[*]

First draft: July 2004
This draft: December 2004

Abstract: This study exploits changes in the catchment areas of public schools in Vancouver, British Columbia to measure the house price capitalization of school quality. Using repeat sales methods to control for time invariant neighborhood effects and disaggregated price indexes to capture time-varying neighborhood price appreciation, we identify significant effects of secondary school performance on residential prices. These effects are limited to homes that experienced large changes in school quality. Our results imply that the prices of residences experiencing the largest improvement in secondary school quality due to the boundary change rose by roughly 4 percent, equivalent to $14,000 for the median home in that area.

† HSBC Professor in Asian Business, Sauder School of Business, University of British Columbia, 2053 Main Mall, Vancouver, BC, V6T1Z2, Canada. Tel: (604) 822-8493, Fax: (604) 822-8477. Email: john.ries@sauder.ubc.ca

* Real Estate Foundation Professorship of Real Estate Finance, Sauder School of Business, University of British Columbia, 2053 Main Mall, Vancouver, BC, V6T1Z2, Canada. Tel: (604) 822-8343, Fax: (604) 822-8477. Email: tsur.somerville@sauder.ubc.ca

---

1 We thank session and seminar participants at Florida, UBC, and the AREUEA International and AsRES conferences for helpful suggestions and insight. We also thank the Vancouver School Board for providing data and information on schools, Landcor for providing us with housing transactions data, and acknowledge funding from the Hampton Committee. The valuable research assistance provided by Sun Hua and GIS consulting services by Oli Helm is greatly appreciated.

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 determining house prices, we use this change 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 house is reassigned to a different catchment area to changes in the house's transaction price. Repeat sales data enable us to control for time-invariant unobserved characteristics of houses and neighborhoods. Consequently, we use temporal changes in house prices to evaluate the cross-sectional variation in local school quality that occurred with reassignment. Our measures of school quality are mainly based on standardized test scores. To control for neighborhood price appreciation, we use the price movements of houses that are not reassigned. We capture 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.

Our results contribute to the empirical literature on the value of school quality in a number of ways. While our hedonic regressions yield results that concord with the literature by identifying significantly positive effects of school test scores on house prices, different results emerge when we employ repeat sales methods. We do not find positive and significant effects for elementary schools. Significant effects for secondary schools only emerge when rezoning generates large changes in school performance. We also find smaller effects of school quality than have other studies, a one standard deviation increase in secondary school quality raises house prices by 1-2 percentage points. Finally, we find that changes in school quality are only priced for particular types of residences—those most likely purchased by high-income buyers.

There is a very long literature that uses hedonic pricing techniques with data on housing prices, housing and characteristics, and school performance, typically student test scores, to measure the capitalization of school quality into housing prices. These efforts began with Oates (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 that are correlated with school performance. As well, there may be selection bias if people with unobserved heterogeneous attributes systematically select into certain neighborhoods. Given that relationship between household income, house prices, local amenities, school resources, and student quality the potential for bias is acute.

The paper valuing school quality using hedonic methods in the current literature that best controls for unobserved neighborhood effects is Black (1999). She captures unobserved neighborhood characteristics by using "boundary fixed effects," comparing the variation in house prices across the border between two attendance districts, where the sample is limited to those houses within a narrow band along the border.[2] The positive effect of elementary test scores drops by approximately 50% when she includes the boundary fixed effects, but it remains statistically significant and large—a one standard deviation increase in elementary test score (5% increase) corresponds to a 1.8-2.1% increase in house value. Black introduces a number of tests to try to ensure that her results are not the result of progression in neighborhood quality or unobserved unit quality. Still, the possibility remains of excluded neighborhood effects leading to positive bias on school quality if the school boundaries also describe neighborhood boundaries.

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 7444 "postcode sectors" in the years 1996-1999. They estimate a hedonic regression using instrumental and semi-parametric techniques. Information on school type 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: they find that a one 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 letter grades to elementary schools in Florida influenced house prices. Their specification includes property and year-neighborhood fixed effects and thus estimates are based 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) 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 (e.g., characteristics of students and school expenditure levels). In their first-difference specification, eighth grading readings score is significant with an elasticity equal to one while most of the controls (12 of 15) enter insignificantly. One shortcoming of their study is that, unless the instruments they use are valid, the estimates school test score effect may be positively biased due to unobserved changes in neighborhoods.

---

[2] Black's use of boundary dummies is a more refined application of the boundary analysis used in Gill (1983) and Cushing (1984).
[3] The exception is house prices in school zones where the school in question received an "A" grade in every year of the analysis.

Furthermore, they use owner estimated value rather than transaction price. This can bias their coefficients upwards since with rising house prices, owners are more likely and better able to finance home renovations, which they tend to over-value (DiPasquale and 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" (page 304). Their sample has few school changes and they occur within a relatively homogenous upper middle class suburb.

The next section provides details about the rezoning. Section II 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. The following section explains how Fourier transformation techniques allow us to compute price indexes for narrow geographic areas and explains our empirical strategy. Section IV contains regression results. We begin by using cross-sectional house and school information and different types of neighborhood fixed effects to show that hedonic regressions reveal a positive association between school quality and residential prices. We include the same boundary neighborhood dummies used in Black (1999). In our repeat sales regressions, we show results for different indexes and 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. The concluding section summarizes the results and interprets them in the context of the existing literature.

I. Vancouver School Rezoning

The Vancouver School Board made the rezoning proposal public in September of 2000. The stated objective of the rezoning was to alleviate overcrowding in certain schools, although examination of the changes reveals that boundaries were adjusted to coincide with major street arteries. 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 of 2001. The change included grandfather clauses both for existing students and any younger siblings not yet in school, but who would attend a school at the same time as did an older sibling.

[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.

Most of the border adjustments were modest changes with multiple schools. For example, the geographic area for Lord Nelson Elementary School increased 12 percent as six city blocks were assigned away to one school and 17 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.

Options to local public schools in Vancouver include public French immersion, private schools, and cross-boundary admission. Each option 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, as we explain in the Appendix, the likelihood of entering a good public school as a cross-boundary applicant is very low

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 pervades location decisions in the U.S. is not present.[5] Second, house preference and location are somewhat unbundled. Vancouver's housing stock is much more heterogeneous than is the case for American suburbs: attached and condominium units make up less than five percent of the transactions in only five of 32 neighbourhoods, and the reverse is true only in the downtown core. Thus we have a sample where preference sorting by house type is less likely to explain our results than in a suburban sample.

II. 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.[6]

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 that "exceed

---

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

[6] We recognize that there is a large debate over what standardized test scores mean and whether they measure school quality or just student characteristics. However, they are commonly used in the literature and have been shown to be capitalized into house values (Brasington, 1999).

expectations, “meet expectations,” and “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 percent of students that exceed expectations by one and the percent that are not yet within expectations by minus one. Then we sum the two (implicitly we are multiplying the percent that meets expectations by zero). 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.[7]

Table 1 shows the correlation of the scores across the years. It ranges between .68 and .80 indicating that, while highly correlated, there is considerable variation in score across years for a given school. This high degree of random variation in student performance is documented by Kane and Staiger (2002) who employ information on elementary school test scores in North Carolina and show that 70% of year-to-year changes in class scores are non-persistent. This large random variation in year-to-year changes in school performance makes it clear that it is better to identify school effects using cross-sectional rather than temporal information. 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.[8] The average across all the schools for 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.

Table 1. Elementary Score Correlation

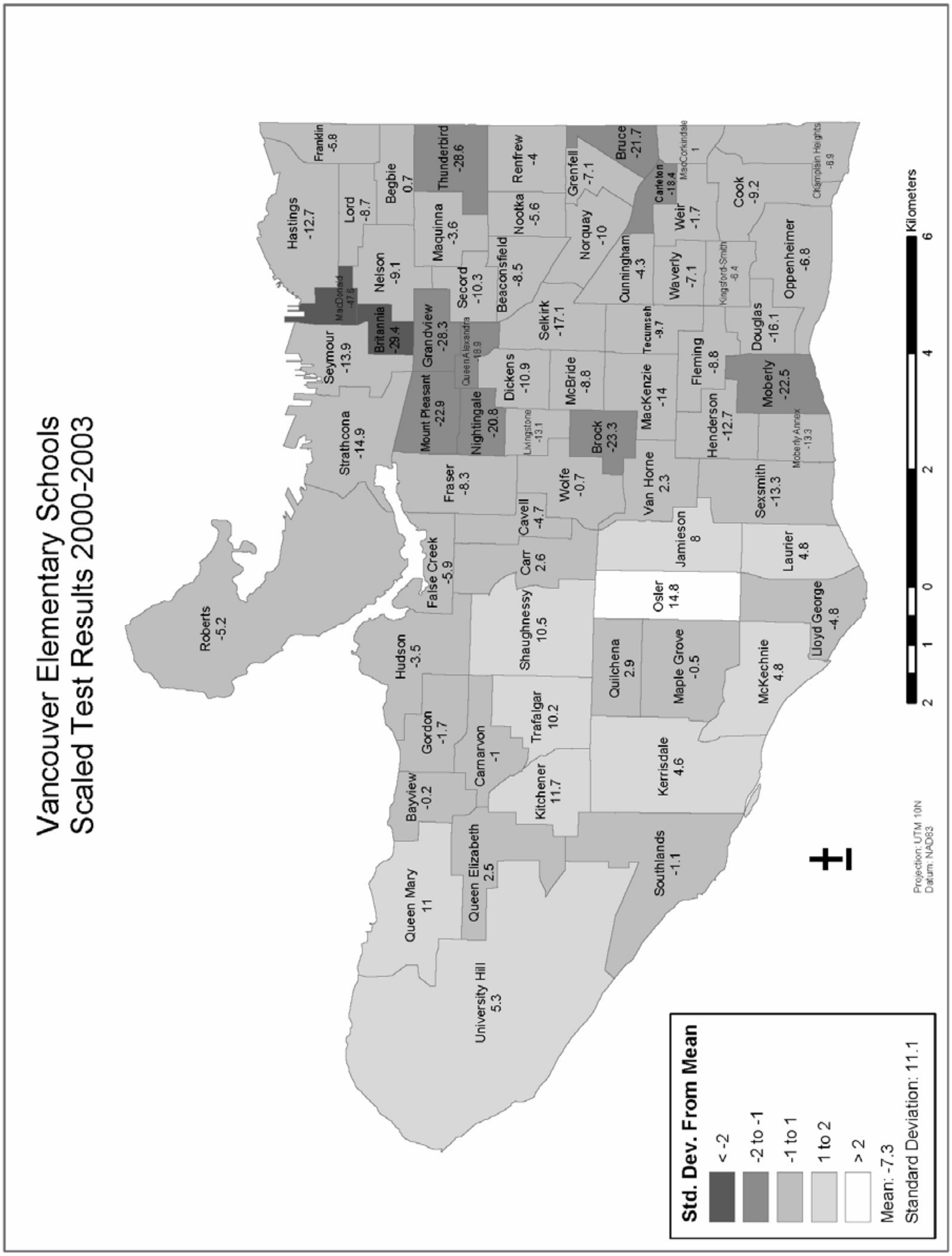
	2000	**2001**	**2002**	**2003**	**average**
2000	1.00				
2001	0.80	1.00			
2002	0.78	0.75	1.00		
2003	0.68	0.69	0.73	1.00	
average	0.91	0.92	0.90	0.85	1.00

Figure 1 shows the post-rezoning distribution of the average 2000-2003 scores by school across the city. We differentiate among the schools by using their score relative to the mean and use shading to identify schools in terms of standard deviations from the mean.

[7] We experiment with two alternative approaches to scoring, one only assigning a point for “exceeding expectations” and one only subtracting a point for “failing to meet expectations.” Our results are quite robust across the different scoring specifications.

[8] 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.

Figure 1


Vancouver Elementary Schools
Scaled Test Results 2000-2003
Std. Dev. From Mean
< -2
-2 to -1
-1 to 1
1 to 2
> 2
Mean: -7.3
Standard Deviation: 11.1
Kilometers
2 1 0 2 4 6
Projection: UTM 10N
Datum: NAD83
Roberts -5.2
Strathcona -14.9
Seymour -13.9
Hastings -12.7
Franklin -6.8
Lord -8.7
Begbie 0.7
Nelson -9.1
Britannia -29.4
Maquinna -3.6
Thunderbird -28.6
Grandview -28.3
Secord -10.3
Nootka -5.6
Renfrew -4
Mount Pleasant -22.9
Beaconsfield -8.5
Grenfell -7.1
Bruce -21.7
Nightingale -20.8
Dickens -10.9
Selkirk -17.1
Norquay -10
Carleton -18.4
McBride -8.8
Cunningham -4.3
Weir -1.7
Cook -9.2
Brock -23.3
MacKenzie -14
Tecumseh -9.7
Waverly -7.1
Fleming -8.8
Douglas -16.1
Oppenheimer -6.8
Henderson -12.7
Moberly -22.5
Fraser -8.3
Wolfe -0.7
Van Horne 2.3
Sexsmith -13.3
False Creek -5.9
Cavell -4.7
Carr 2.6
Jamieson 8
Laurier 4.8
Hudson -3.5
Shaughnessy 10.5
Osler 14.8
Lloyd George -4.8
Quilchena 2.9
Maple Grove -0.5
McKechnie 4.8
Gordon -1.7
Trafalgar 10.2
Carnarvon -1
Bayview -0.2
Kitchener 11.7
Kerrisdale 4.6
Queen Mary 11
Queen Elizabeth 2.5
Southlands -1.1
University Hill 5.3

The figure shows that the better schools are on the wealthier west side of Vancouver.[9] 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 neighborhood from MacDonald to Nelson these homes would now be zoned in school with students that perform much better on the FSA.

Secondary schools

For secondary school quality, we use the rankings of the Fraser Institute, a non-partisan think tank located in Vancouver. The Institute gives each school a score on a ten-point scale based on eight criteria, which we multiply by 10 to compare with elementary schools.[10] The key data are from the Provincial Examinations usually taken by 12th 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.[11] Table 2 lists the correlations across secondary schools between the five-year score ending in year 2000 and more recent annual scores. With correlations exceeding .91, we find that secondary scores are much more correlated than what we observe for elementary school scores.

Table 2. Secondary Score Correlation

	2000	**2001**	**2002**	**5-yr, 96-00**
2000	1.00			
2001	0.92	1.00		
2002	0.94	0.91	1.00	
5-yr, 96-00	0.97	0.92	0.96	1.00

Figure 2 shows the pre-rezoning boundaries of these schools and their 1996-2000 Fraser Institute score. There is substantial variation in performance across schools with University Hill, located on the west side near to the University of British Columbia, received a five-year score of 95.2 whereas John Oliver, 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. A swath of neighborhoods on the western edge of the east side of Vancouver, zoned originally in poor-performing Tupper and Oliver, moved to west side

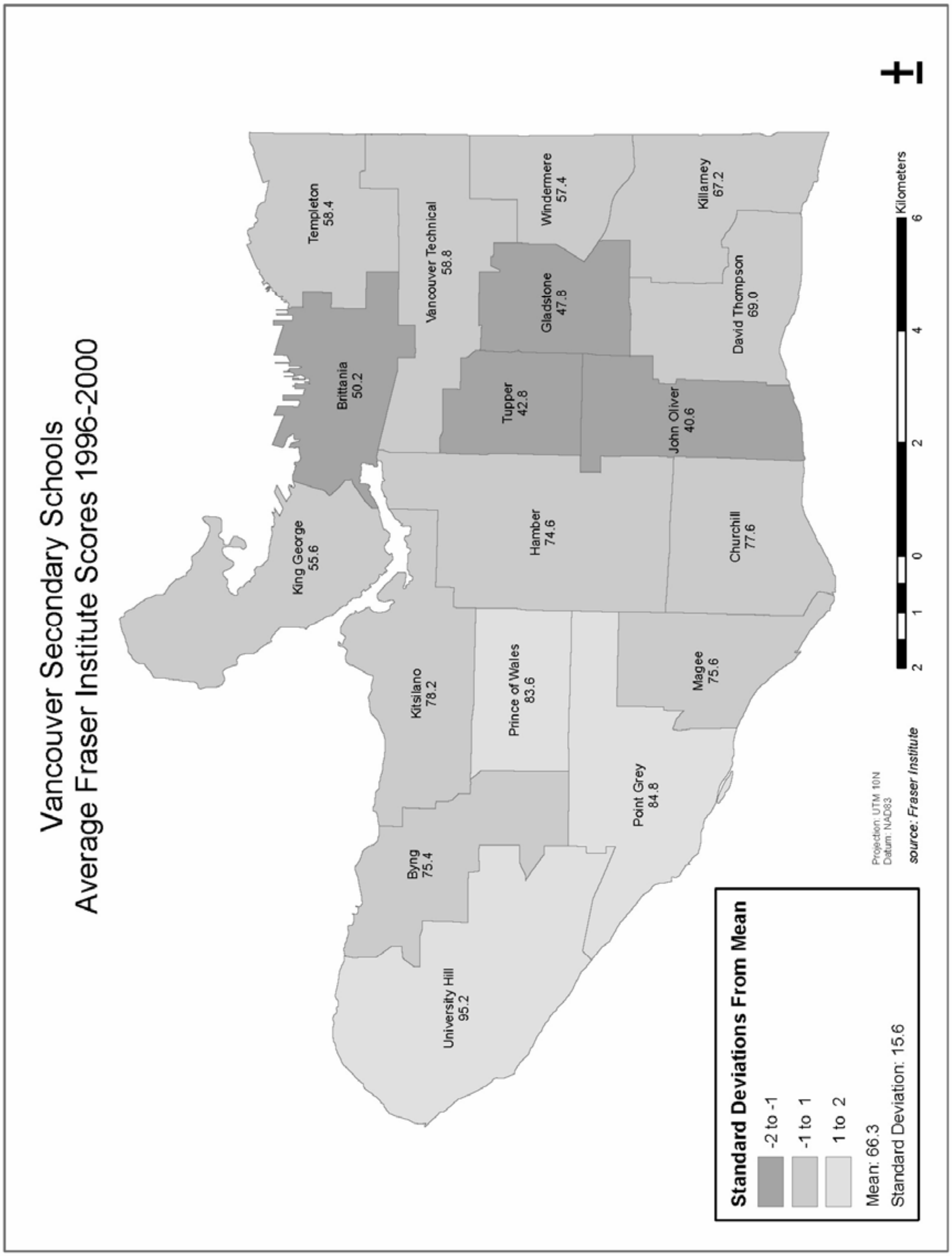
[9] The mean west side house price is $414,500 while on the east side it is $283,000, though unit area and lot size are nearly the same.

[10] 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 vs. exam mark difference - 10%, English 12 gender gap - 5%, Math 12 gender gap - 5%, exams taken per student - 20%, graduation rate - 10%, and composite dropout rate - 10%. The "school vs. exam mark difference" indicates when provincial exam marks deviates from marks awarded in the school while the gender gap indicates differences in male and female exam performance relative to performance in the school. Each of the eight components is converted into a "Z" score before the weighting is applied.

[11] The average exam score recorded by the Fraser Institute is based on total exams taken. Because this varies across schools, we do not use it alone as a measure.

schools with the boundary changes. These neighborhoods will be critical sources of variation in school quality in our regression estimates.

Figure 2



B. House Price Data

Our housing data are based on the complete universe of residential transactions in Vancouver for the period 1996-2003 provided by Landcor from the British Columbia Assessment Authority (BCAA) records of transactions determined to be arm's length by BCAA. We then obtain all previous sales for each of these transactions, back to 1974. Thus, unlike most repeat sales indexes that discard large amounts of data by only looking at units that transact twice in a single period, we ensure that we have observations for nearly all transacting units in our period of interest.[12] The major exception will be newer units that transacted only once. We discard units with commercial and residential properties mixed together, that transact twice on the same day, and with transaction prices below $10,000 per unit, leaving us with 90,553 transactions.

One of the problems with repeat sales analysis is that 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 dataset only reports current unit structure characteristics, so we are not able to track changes in unit size over time.[13] However, BCAA does include a variable that indicates the most recent year in which a building permit was issued for the address. We use this to control for major structural changes by designating transactions prior to this date as belonging to a "different" unit. Since this means that in some cases we no longer have a repeat sale, this further reduces our data to 87,381 observations, of which 22,476 occur after September 2000 when the border changes were made public. For the analysis we only keep the first post September 2000 transaction. This further drops our sample to 19,225 effective observations for this period.

BCAA disaggregates Vancouver into 32 neighborhoods for the purpose of assessment. The goal of their allocation is to create a balanced workload for their assessors while retaining a degree of neighbourhood homogeneity. The BCAA boundaries do not perfectly match Vancouver School Board school attendance zone boundaries and generally respect the split between the west and east sides of Vancouver (only deviating in the high density downtown core where many new high rise condominium buildings have been constructed, particularly in the last three years). The BCAA neighborhoods provide us with an exogenous and accepted way to introduce neighborhood effects either as a fixed effect or through neighborhood specific price indexes.

III. Empirical Methodology

Our empirical strategy is to test the relationship between the changes in school quality resulting from the reassignment of a house from one school boundary zone to another

[12] Any units that transacted twice during 1996-2003Q3, but not prior to 1996 are also included. Our coverage gets sparse before 1996, but our goal is to identify price changes after 2000Q3, so this should not pose a problem for our analysis.
[13] Structure characteristics are limited to lot size, unit size, number of bedrooms, and unit age.

against the change in house prices. In this differences-in-differences approach, we expect that following the announcement of the changes in school boundaries, house prices will increase faster the larger the gap between the old and new schools

Our identification is based on residences that transacted after September 2000 where rezoning moved the residence from one school attendance zone to that of another adjacent school. Figures 3 and 4 identify the transactions from which we get this identification, 1,849 for secondary schools and 1,941 for elementary school. There are only 78 transactions where rezoning resulted in changes in both elementary and secondary schools.

There are 75 areas where rezoning resulted in distinct combinations of old and new elementary schools. Among these, 22 experienced absolute changes in school quality of greater than one standard deviation in the initial distribution of school scores. Rezoning led to changes in secondary schools for 25 areas with seven of these areas experiencing changes of greater than one 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.

In Figures 3 and 4, we identify the areas that experienced large changes in school quality. Transactions associated with school changes greater than one standard deviation are denoted by "+" for positive changes and "-" for negative changes. We also 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. What is striking about this identification, is that the "better' school in a pair typically has a test score below the district mean. The exceptions are the movements from Brock to Wolfe or Van Horne to Brock. As shown in Figure 4, the truly significant changes in secondary schools come from movements from the two lowest rated schools, Tupper and John Oliver, to two above average schools, Hamber and Churchill. These changes represent a greater than two standard deviation movement up in the distribution of Vancouver public secondary schools.

The important methodological consequence of the distribution on school quality changes resulting from border changes shown in Figures 3 and 4 is that we will have to make sure we control for movements in housing prices in as disaggregated a neighborhood as possible. This creates challenges because the standard approaches to measuring house prices, hedonic and repeat sales techniques, break down at highly defined areas of disaggregation because of the absence of the large numbers of observations needed to address the "imprecision" in housing prices.

Figure 3

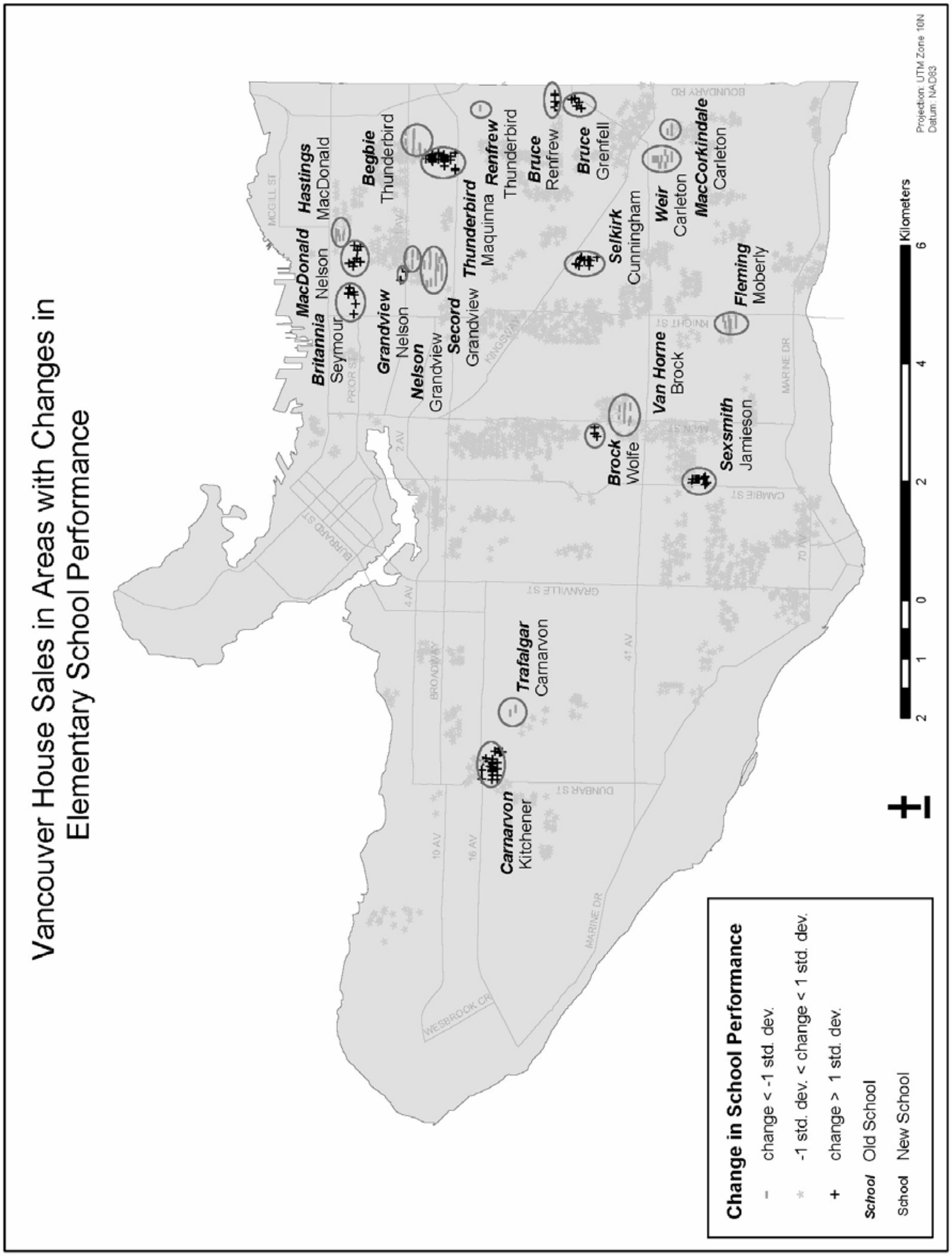
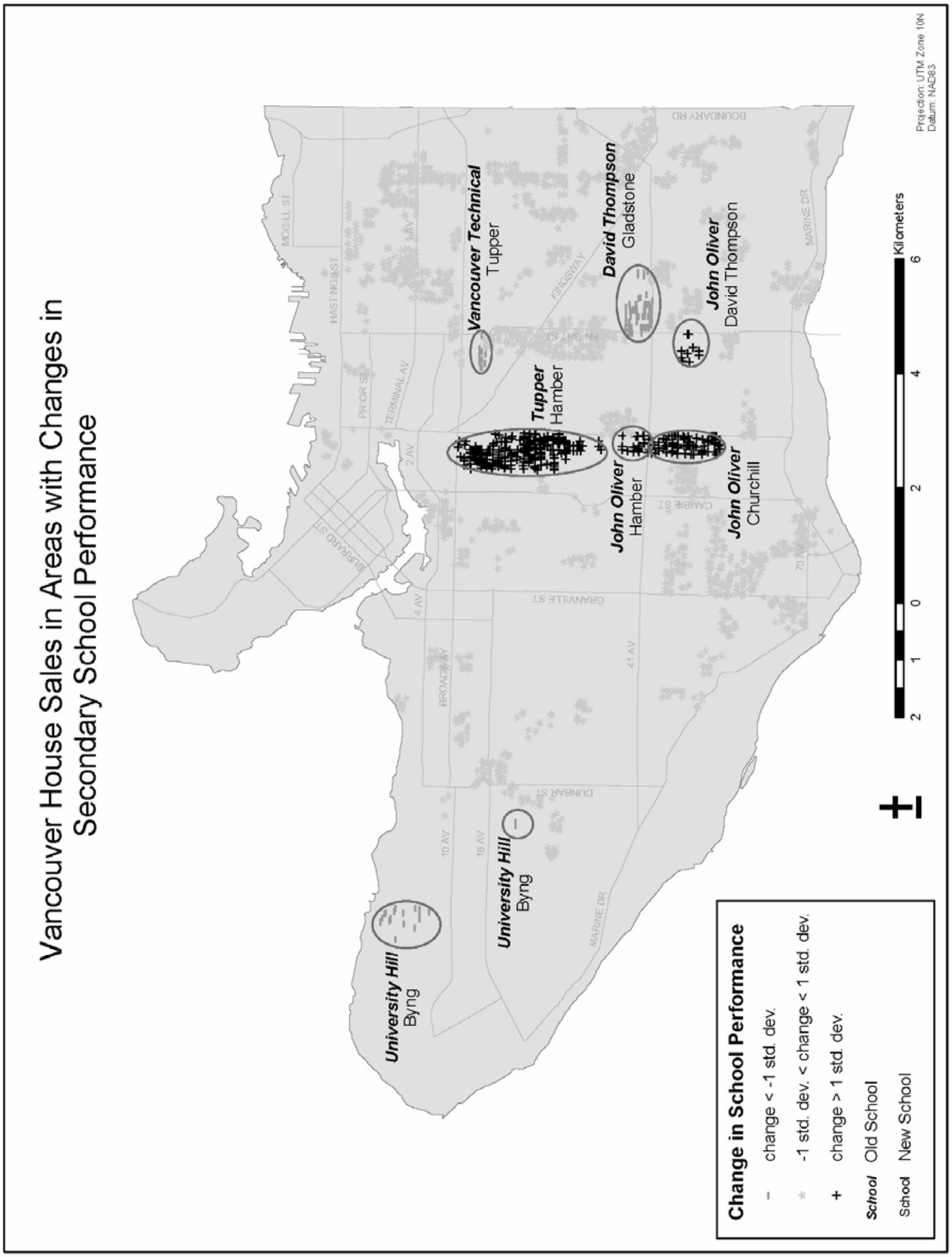

Vancouver House Sales in Areas with Changes in Elementary School Performance
Change in School Performance
change < -1 std. dev.
-1 std. dev. < change < 1 std. dev.
change > 1 std. dev.
School Old School
School New School
Kilometers
Projection: UTM Zone 10N
Datum: NAD83

Figure 4


Vancouver House Sales in Areas with Changes in Secondary School Performance
University Hill
Byng
Vancouver Technical
Tupper
Tupper
Hamber
David Thompson
Gladstone
John Oliver
David Thompson
John Oliver
Hamber
John Oliver
Churchill
Change in School Performance
– change < -1 std. dev.
-1 std. dev. < change < 1 std. dev.
+ change > 1 std. dev.
School Old School
School New School
Kilometers
2 1 0 2 4 6
Projection: UTM Zone 10N
Datum: NAD83
DUNBAR ST
GRANVILLE ST
CAMBIE ST
KNIGHT ST
BOUNDARY RD
BROADWAY
41 AV
KINGSWAY
MARINE DR

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*, market conditions at time *t*, school quality S for school attendance zone *s*. In the standard semi-log formulation under an assumption that structure, neighborhood, and school quality characteristics are time invariant:

$$\ln(P_{inst}) = \alpha_t + \beta X_i + \delta S_s + \gamma N_n + u_{isnt} \tag{1}$$

The concern over bias comes from unobserved time invariant components of vector N that are correlated with the observed characteristics, and typically we would expect better schools to be located in neighborhoods with nicer, better maintained, higher quality houses and better neighborhood amenities, where typically all of the latter have at least some element that is not observed. In the housing literature, repeat sales methodology first associated with Bailey, Muth and Nourse (1963), is typically used to control for any unobserved time-invariant parameters. Between any two periods *t* and *t+j* the change in underlying house prices is:

$$\ln\left(\frac{P_{in,s,t+j}}{P_{in,s,t}}\right) = \alpha_{t+j} - \alpha_t + u_{isn,t+j} - u_{isn,t} \tag{2}$$

The estimation approach is to regress the log price ratio on dummies 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.

We examine houses that "move" from one school attendance area to another, so for a change school *s* to school *s+k* we would have:

$$\ln\left(\frac{P_{in,s+k,t+j}}{P_{in,s,t}}\right) = \alpha_{t+j} - \alpha_t + \delta(S_{s+k} - S_s) + u_{i,s+k,n,t+j} - u_{isn,t} \tag{3}$$

The challenge is to differentiate between the evolution in the level of house prices ($\Delta\alpha = \alpha_{t+j} - \alpha_t$) from the effect from the change in schools ($\Delta S = S_{t+k} - S_t$). We will use repeat sales transactions for houses that remain in the same school attendance area to identify the former, and get our identification of δ from those houses that change elementary and/or secondary school attendance zones. This presupposes no difference in underlying price appreciation rates, while allowing for differences in price levels within a neighborhood.

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 upwards bias if the houses that transfer from the attendance zones of low quality schools to those of higher quality schools are located in neighborhoods that are experiencing faster price appreciation than the city as a whole. For instance, we may have high-income people selecting into certain neighborhoods due to some unobserved change in neighborhood characteristics such as better policing, a new park, or gentrification. To obviate this concern we need our price indexes (α_n) to be as geographically disaggregated as possible.

Using a conventional BMN repeat sales approach to do so is challenging because the methodology requires two transactions of the same house in the period of analysis and there needs to be a transaction in every period. As well, housing is a heterogeneous goods 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. Without large sample sizes, repeat sales price indexes can be extremely noisy. For large geographic areas that is not typically a problem, but it does limit the ability to construct reasonable indexes at more detailed levels of geography such as neighborhoods.[14] In our data, there are no paired transactions in at least one quarter after the school boundary change in five of our 32 neighborhoods. To address this problem with the BMN methodology, we apply 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 non-existent, making it ideal for price index construction at the neighborhood level, an application used by McMillen (2003).

The Fourier expansion approach assumes that there is 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:

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

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

$$\begin{aligned} \ln(\frac{P_{in,s,t+j}}{P_{in,s,t}}) &= \tau_1(z_{t+j} - z_t) + \tau_2(z_{t+j}^2 - z_t^2) + \\ &\sum_q \lambda_q \{\sin(qz_{t+j}) - \sin(qz_t)\} + \rho_q\{\cos(qz_{t+j}) - \cos(qz_t)\} + u_{isn,t+j} - u_{isn,t} \end{aligned} \tag{5}$$

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.

[14] The housing literature is rich in studies that examine the problems with repeat sales indexes, including sample selection problems.

Figure 5

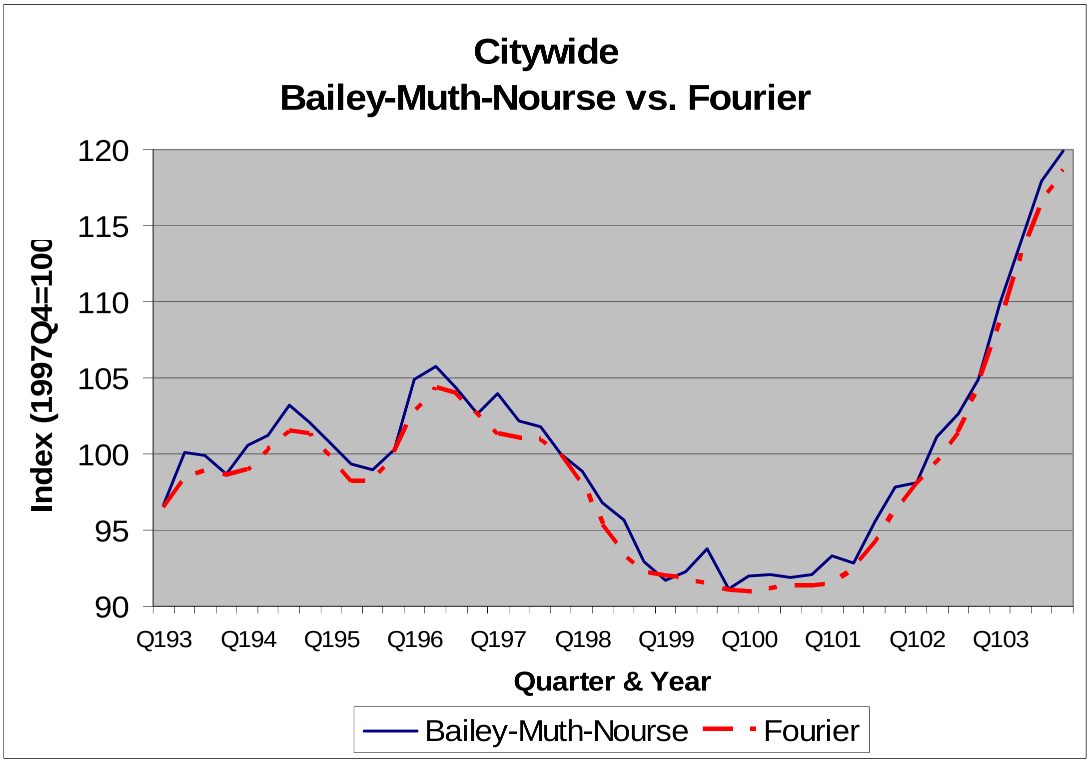
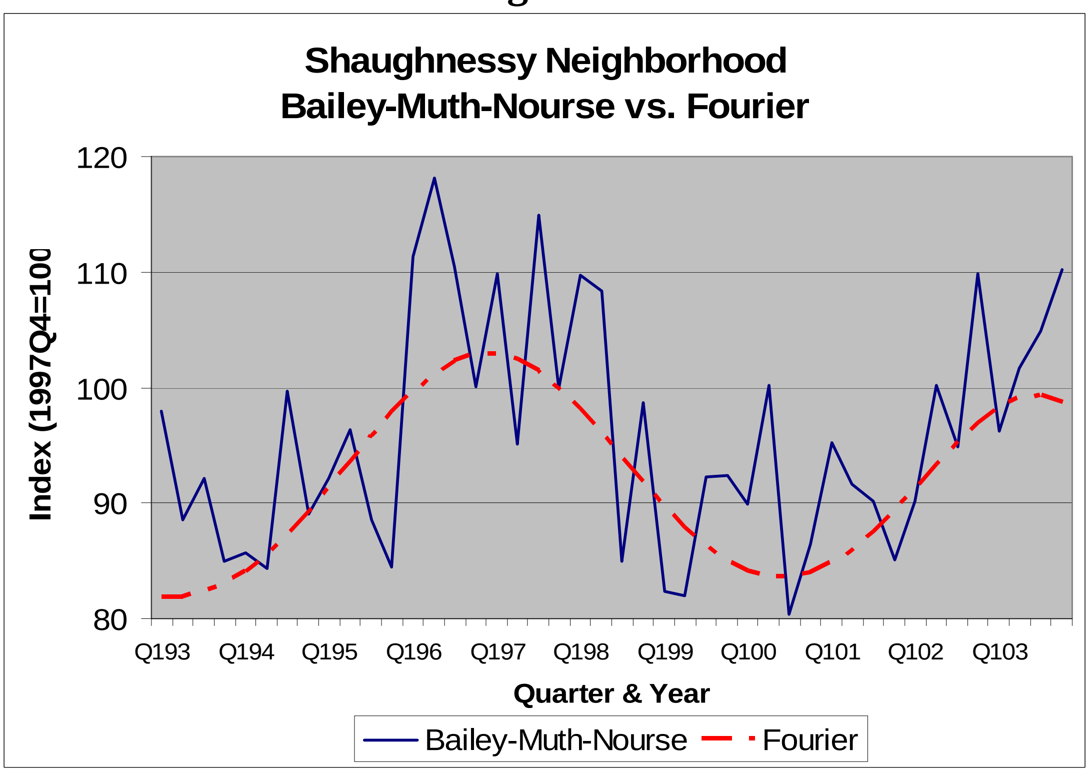


Figure 6

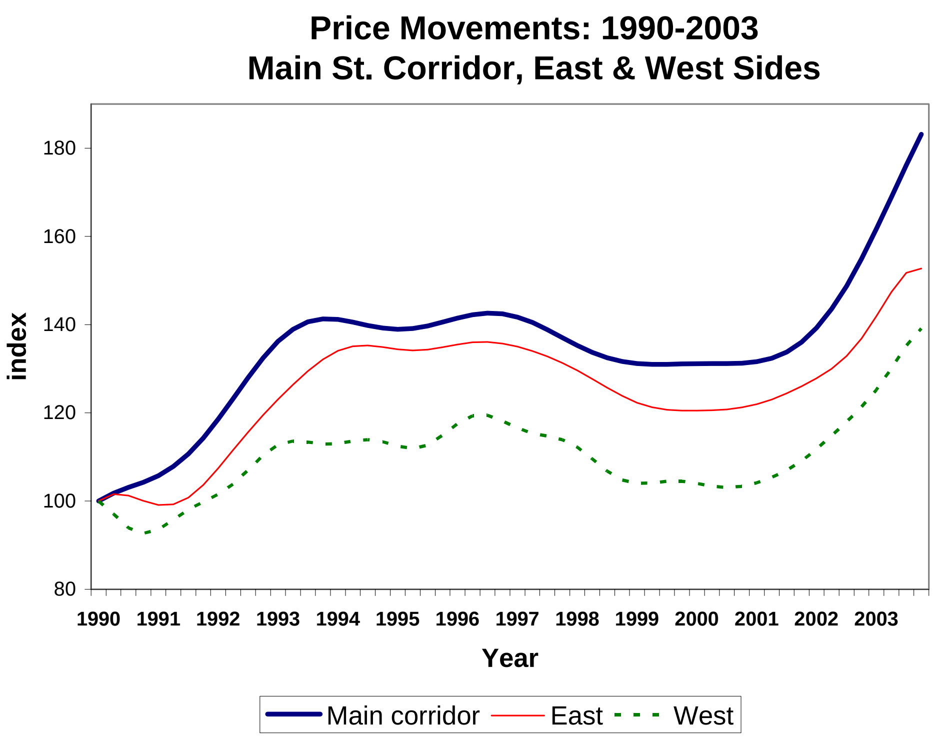


Figures 5 and 6 show the difference between a standard BMN repeat sales index and one created using the Fourier smoothing technique. For the citywide data (Figure 5), where the sample size is large, the difference is not meaningful. However, when we use more disaggregated data in Figure 6 (defining the market at the BCAA neighborhood level for the neighborhood of Shaughnessy), the effect of smoothing becomes more apparent. Comparing the two series, they 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.[15] This raises a concern that 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, than the school price effect will be correlated with this excluded effect and be biased upwards. 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, a period that encompasses the repeat sales pairs for 79% of the 19,225 transactions used in the regressions. Over this period, residential prices rose fastest in the Main corridor, 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.

Figure 7

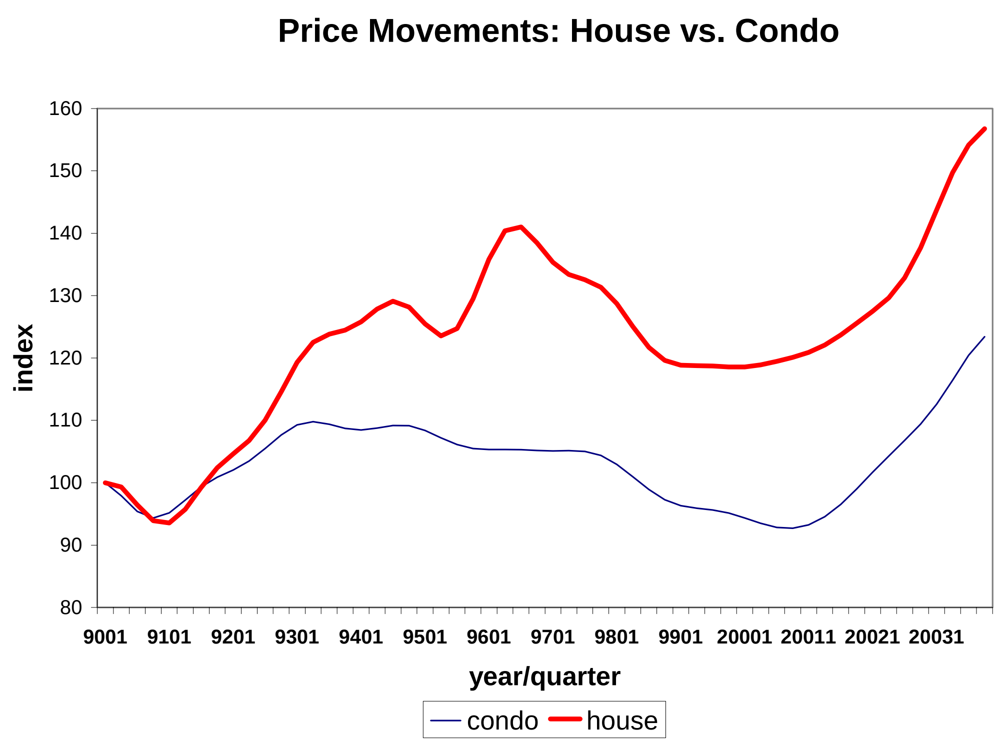


[15] Of the 442 transactions after September 2000 for houses whose catchment area change improved their secondary school by at least two standard deviations, 227 occur within 250m of Main St.

Houses versus condos

Our data set includes four main types of properties—single family dwellings, row houses, duplexes, and strata-title residences (principally condos). Rather than focus on single-family houses like much of the previous literature, we include all these properties since many have two or more bedrooms and are places where families reside in Vancouver. However, prices changes may vary by type of residence. To control for this, we compute separate prices indexes for two groups of properties: strata-title properties and others. For convenience, we will refer to strata-title properties as condos and non-strata 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.

Figure 8



IV. Results

We begin by estimating school quality effects using a hedonic approach expressed in equation (1),

$$\ln(P_{inst}) = \alpha_{nt} + \beta X_i + \delta S_s + \gamma N_n + u_{isnt} \tag{1}$$

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 time period 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 deviations of average scores across schools. Secondary school score is the 1996-2000 rating by the Fraser Institute normalized by the standard deviations of these ratings across schools. Our sample of 9719 homes is the set that transacted after the announcement of boundary changes in September 2000 for which we have all housing characteristics.

Table 3 lists results of the hedonic regressions. Column (1) does not employ fixed effects whereas each ensuing columns show results with different types of fixed effects: Column (2) uses a dummy variable to capture Vancouver west side and column (3) dummy variables for the 32 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.[16] Specifications (1) and (2) 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 and, 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 3 reveals that after controlling for house characteristics and neighborhood effects, school scores are positively and significantly associated with housing prices.[17] Since the scores are normalized by the standard deviation, the coefficients are interpreted as the percent change in house value associated with a one 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 are larger number of fixed effects, the coefficients fall but remain statistically significant. The coefficients for elementary test scores are somewhat smaller than those reported by Black (1999). For the narrowest boundary region, a one standard deviation increase in performance is associated with a 0.7 percent increase in house prices, as compared to 2.1 percent in her study. The effect of secondary scores tends to be higher than that of elementary score, 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.

[16] Black defines boundary areas as .35 miles, .20 miles, and .5 miles from the boundary, roughly comparable to our areas.
[17] Unreported coefficients on house characteristics have the expected signs.

Table 3. Hedonic Regressions

Spec.		(1)	(2)	(3)	(4)	(5)	(6)
1	Elem. Score	0.177*** (0.022)	0.044*** (0.012)	0.021*** (0.006)	0.013*** (0.004)	0.011** (0.004)	0.007* (0.004)
	Obs.	9719	9719	9719	9309	8367	6892
	R-square	0.757	0.829	0.851	0.859	0.855	0.853
2	Sec. Score	0.194*** (0.035)	0.044*** (0.012)	0.023*** (0.008)	0.040*** (0.011)	0.029*** (0.010)	0.013** (0.005)
	Obs.	9719	9719	9719	6585	4977	3617
	R-square	0.772	0.829	0.851	0.857	0.859	0.860
3	Elem. Score	0.102*** (0.016)	0.038*** (0.011)	0.018*** (0.006)			
	Sec. Score	0.136*** (0.016)	0.036*** (0.010)	0.020** (0.008)			
	obs.	9719	9719	9719			
	R-square	0.792	0.831	0.851			
Fixed Effects		none	east-west	BCAA	Boundary 500m	Boundary 350m	Boundary 250m

Note: *,**,*** 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 now turn our repeat sales specification that allows us to relate changes in school quality due to rezoning and within residence changes in prices,

$$\ln\left(\frac{P_{in,s+k,t+j}}{P_{in,s,t}}\right) = \alpha_{n,t+j} - \alpha_{n,t} + \delta(S_{s+k} - S_s) + u_{i,s+k,n,t+j} - u_{isn,t} \qquad (3)$$

Recall the key issue is differentiating between the evolution in the level of house prices ($\Delta\alpha$) from the effect from the change in schools (ΔS). 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 price indexes are calculated using only transactions of houses that do not change schools so that the effect of $\Delta\alpha$ is orthogonal to ΔS.[18] The key variable of interest, the change in school score (ΔS), is non-zero only in the case where a house is not reassigned. Finally, the standard errors are adjusted to allow for correlations across errors for residences that share common secondary and elementary schools before rezoning.

[18] To be precise, to compute the indexes we use price information from all transactions before the September 2000 announcement of boundary changes and price information on units that were not rezoned for transactions subsequent to the announcement.

We confine the analysis to regressions where we allow for different price indexes for houses and condos. Figure 8 provided compelling evidence that prices for these different types of residences evolved differently, and allowing for separate indexes yields a better regression fit. Table 4 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 city-wide index. The next two columns use indexes based on the catchment areas for the 18 secondary schools, with column (2) based on the pre-rezoning catchment areas (old sec.) and column (3) based on the post-rezoning catchment areas (new sec.). Column (4) reflects results when indexes are created for the 32 BCAA neighborhoods and column (5) indexes for separately for the west and east side 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 strata transactions in a few neighborhoods.

House price regressions can 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 one percent 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 4: School Boundary Change (Repeat Sales), Different Indexes

Full Sample	(1) City wide	(2) Old sec.	(3) New sec.	(4) BCAA	(5) W-E-Main
Price index	0.984***	0.981***	0.979***	0.983***	0.980***
	(0.009)	(0.001)	(0.005)	(0.004)	(0.008)
Elem. Score	-0.024*	-0.013*	-0.013*	-0.005	-0.023*
	(0.013)	(0.007)	(0.007)	(0.007)	(0.012)
Sec. score	0.022**	0.008	0.044***	0.015*	0.016
	(0.010)	(0.006)	(0.011)	(0.008)	(0.011)
obs	19225	19082	19076	18902	19225
R-square	0.831	0.847	0.846	0.852	0.838
No Tails					
Price index	0.991***	0.988***	0.987***	0.991***	0.987***
	(0.009)	(0.005)	(0.004)	(0.005)	(0.008)
Elem. Score	-0.021*	-0.009	-0.009	-0.002	-0.020*
	(0.012)	(0.006)	(0.006)	(0.017)	(0.010)
Sec. score	0.024***	0.010**	0.046***	0.017***	0.018*
	(0.008)	(0.005)	(0.009)	(0.006)	(0.010)
obs	18522	18488	18469	18522	18522
R-square	0.870	0.887	0.885	0.892	0.877

Note: *,**,*** 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.

Table 4 reveals that positive effects for changes in secondary school performance due to rezoning and negative effects for changes in elementary school performance. The magnitude of the estimated effects indicates that a one standard deviation change in secondary school performance is typically associated with a 1-2 percentage point change in house price appreciation. The negative elementary school effect is perverse, although it becomes statistically insignificant once we eliminate the 1% tails of the distribution and use the more disaggregated price indexes.[19] The secondary school effect tends to be significant, especially in the "no tails" regressions. 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 relatively low price index of the west side to the properties in the Main corridor that experience very large increases in secondary school performance due to the rezoning.

We note that the coefficient on the price index tends to be very close to one but is often significantly smaller than one. This is a consequence of using the Fourier transformation and disaggregated price indexes (even the city wide 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.[20] Eliminating the extreme observations moves the coefficient of the price index closer to one.

Table 5 portrays results when we allow the school effect to differ depending on the size of the change in schools resulting from rezoning. The idea is that when test scores give a noisy signal of school quality, people may care more when changes are large than they do when they are small. Indeed, there is enough variation is school performance from year to year that small observed differences in school performances are sometimes reversed over time, a finding consistent with Kane and Staiger (2002). For example, in 2000, Kitsilano Secondary was rated higher than Lord Byng Secondary but by 2003 their relative ranking reversed. On the other hand, poorly performing secondary schools such a Tupper and John Oliver are always rated much lower than Hamber and Churchill. We define changes in school performance exceeding one standard deviation as "large Δ" and less than one standard changes as "small Δ". Here, as in all the remaining tables, we report results for the sample that excludes the extreme observations.

Table 5 reveals that the negative elementary school effects are confined to areas where rezoning resulted in relatively minor changes on school quality. In the large change areas, the effects are very close to zero. Since relatively small differences in elementary school quality caused by rezoning would be unlikely to move residential prices, we suggest that the negative price movements exhibited in these areas were not caused by school rezoning, rather some other factor that we do not observe. Examining the estimates on secondary school score, we observe the coefficients in large change areas are positive and

[19] As mentioned previously, these elementary school results, including the marginally significant and negative signs are robust to different ways to score these schools.
[20] We have experimented with specifications constraining the coefficient to one the price index to be one and the qualitative results are unaffected.

significant. When using the BCAA index, a one standard deviation increase in school performance is associated with a 1.8% increase in price. In the Tupper-to-Hamber, Tupper-to-Churchill, and Oliver-to-Churchill areas, the change in school quality exceeds two standard deviations (2.04, 2.18, and 2.37, respectively) implying a 3.5% to 4.0% increase in prices.

Table 5: School Boundary Change (Repeat Sales), Different Indexes, Separate Effects for Large and Small Changes in School Quality, No tails Sample

		(1) City wide	(2) Old sec.	(3) New sec.	(4) BCAA	(5) W-E-Main
Price index		0.991*** (0.009)	0.988*** (0.004)	0.986*** (0.005)	0.991*** (0.004)	0.987*** (0.008)
Elem. score	Large Δ in School Quality	-0.006 (0.009)	-0.005 (0.007)	-0.004 (0.007)	0.006 (0.008)	-0.004 (0.009)
	Small Δ in School Quality	-0.052* (0.029)	-0.019* (0.011)	-0.019* (0.011)	-0.020** (0.010)	-0.054** (0.022)
Sec. score	Large Δ in School Quality	0.026*** (0.007)	0.010** (0.004)	0.051*** (0.008)	0.018*** (0.006)	0.021** (0.009)
	Small Δ in School Quality	-0.003 (0.048)	0.013 (0.045)	-0.030 (0.036)	-0.004 (0.029)	-0.025 (0.040)
Obs		18522	18488	18469	18522	18522
R-square		0.870	0.887	0.886	0.892	0.877

Note: *,**,*** 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. Small Δ areas are school changes of less than one standard deviation whereas large Δ areas are changes of more than one standard deviation. 1% tails from regression of house price change on price index are excluded.

Up to now we have considered heterogeneity in terms of geography. However, residential sub-markets may breakdown by unit type as well. In Table 6 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 whether they: 1) have 2 or more bedrooms; 2) have 3 or more bedrooms; 3) are in the top half in terms of unit area (greater than 1332 square feet); and 4) have a lot size exceeding 2000 square feet. We report results using the BCAA prices indexes since this is the most disaggregated price index and the results above indicate it best fits the data. The sample sizes in these regressions are reduced due to incomplete information on unit characteristics.

We find no significant differences in coefficients by house size. The coefficients on school quality in Table 6 for each specification are within one standard deviation of each other. The difference is greatest and of the "reverse" sign for the lot area specification (4). The results are sensitive to whether we consider the 4718 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 0.16 and is significantly different from zero at the 5% level whereas that for non-family oriented units is lower and insignificantly different than zero (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).

Table 6: School Boundary Change (Repeat Sales), Effects for Family vs. Non-Family Oriented Units

		(1)	(2)	(3)	(4)
Definition of family oriented		2 or more bedrooms	3 or more bedrooms	unit area > 1332 feet	lot size > 2000 feet
Price index		0.989*** (0.004)	0.989*** (0.004)	0.989*** (0.004)	0.989*** (0.004)
Elem. score	Family oriented	-0.003 (0.007)	-0.005 (0.007)	-0.003 (0.007)	-0.008 (0.008)
	other	-0.011 (0.016)	0.001 (0.011)	-0.003 (0.011)	0.014 (0.019)
Sec. score	Family oriented	0.016** (0.010)	0.013* (0.012)	0.015** (0.012)	0.013* (0.008)
	other	0.012 (0.017)	0.020*** (0.007)	0.015** (0.005)	0.022*** (0.006)
Obs		17351	17351	17344	17351
R-square		0.893	0.893	0.893	0.893

Note: *,**,*** 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 non-family based on splitting the same according to criteria indicated in the top row. 1% tails from regression of house price change on price index are excluded.

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 7, the median price of a unit with two or more bedrooms was $320,000 whereas it is $147,900 for less than two bedroom units (mostly condos). The estimated coefficients in Table 6 approximate percentage increase in house prices associated with a one standard deviation increase in school scores. Combining price information with the estimates shown in column (1) implies that the 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.

Our results in Table 6 are quite different than those in Black (1999) who finds houses with three bedrooms or more benefit most from better school performance. One interpretation of the limited support for differential school effects for family and non-family oriented units is that unobserved neighborhood effects are causing prices to rise on all units (i.e., our results are spurious). There are two counter-arguments to this view. First, the benefits of good schools may have a similar dollar effect across types of houses. Second, since residential properties can be altered to accommodate families wishing to access good neighborhood schools, our results are consistent with the urban economics literature where benefits of location are capitalized into *land* values. These arguments explain the results in column (4), where the *percentage* effect is greater for smaller, cheaper lots.

Our final test of heterogeneity allows for differences in preferences across households. We split the sample into quartiles based on the price per square foot of housing. This is a better test of per person housing demand than house price since, given a particular preference for unit size, high income households will purchase higher quality, more expensive units. Our motivation for this test is that with an income effect, purchasers of high-end properties have higher incomes and have a greater willingness to pay for good schooling. We use the BCAA price index to control for neighborhood price movements.

Table 7: School Boundary Change (Repeat Sales), Effects by House Price/Sq. Ft. Quartile

	(1) Price/Sq. Ft. Bottom Quartile	(2) Price/Sq. Ft. 2nd Quartile	(3) Price/Sq. Ft. 3rd Quartile	(4) Price/Sq. Ft. Top Quartile
Price index	0.939*** (0.007)	0.985*** (0.009)	0.976*** (0.009)	1.039*** (0.007)
Elem. Score	-0.003 (0.008)	-0.010 (0.016)	-0.004 (0.011)	0.021 (0.018)
Sec. score	-0.003 (0.012)	0.000 (0.010)	0.029* (0.015)	0.036*** (0.009)
Obs	4357	4356	4357	4356
R-square	0.894	0.857	0.883	0.918

Note: *,**,*** 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. 1% tails from regression of house price change on price index are excluded.

The results in Table 7 are quite striking. Uniformly the coefficients on the change in school quality are highest for the top quartiles, where house price per square foot is greatest. Column (4) reveals that the coefficient on elementary school quality is positive and at least one standard deviation above zero. These results are not being driven by the large school quality change observations, as the units with at least a two standard deviation change in secondary school scores are reasonably distributed across each quartile.

V. Conclusion

The rezoning of public schools in Vancouver in 2000 provides a natural experiment for investigating the effects of school quality on housing prices. Since after the rezoning individual residences were moved into catchment areas of different schools, 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 house and condos.

Despite positive and significant elementary school effects in hedonic regressions, we do not find that rezoning of elementary schools leading to large changes in school quality had a statistically significant effect on house prices. One explanation for this result is that elementary school variation within a school district is not viewed as being important. Other studies have found significant elementary school effects although no study can definitively reject the proposition that unobserved factors bias the estimates, especially those employing hedonic methods. Since most existing studies control for elementary school test scores but not secondary school performance, perhaps the coefficient on elementary schools is partly picking up secondary school effects. Another explanation is that the large elementary school changes occurred in low-income neighborhoods and that this segment of the population has a low willingness to pay for school quality.

We do find effects for secondary schools rezoning for houses that experienced large changes in performance. Estimates using the most disaggregated neighborhood price indexes imply that a school standard deviation increase in school performance corresponds to a 1.8% increase in the price residences in Vancouver. Houses that moved from poorly performing Tupper and Oliver Secondary Schools to strongly performing Hamber and Churchill Secondary Schools realized a more than two standard deviation improvement rise in the school distribution and thus enjoyed significant price increases due to the rezoning. For our sample, the median price for homes in these areas was $350,000 implying that rezoning led to about a $14,000 increase in price.

We do not find evidence that the percentage increase in house prices due to an improvement in secondary schools was highest on family-oriented units, although the level increase in price was highest for these units. However, prices rose fastest on residences most likely to be purchased by high income buyers. This last result suggests unobserved unit quality is likely to be correlated with the valuation of education, biasing upwards the coefficients on school quality in cross-sectional regressions.

References

Bailey, M.J., Muth, R.F., and H.O. Nourse. 1963. "A Regression Method for Real Estate Price Index Construction," Journal *of the American Statistical Association*, 58, 933-942.

Black, S. E. 1999. "Do Better Schools Matter? Parental Valuation of Elementary Education." *Quarterly Journal of Economics*, 114, 577-600

Bogart, W.T. and B.A. Cromwell. 2000. "How Much is a Neighborhood School Worth?" *Journal of Urban Economics*, 47, 1-25.

Brasington, D.M. 1999. "Which Measures of School Quality Does the Housing Market Value?" *Journal of Real Estate Research*, 18(3) 395-413.

Cushing, B. J. 1984. “Capitalization of Interjurisdictional Fiscal Differentials: An Alternative Approach,” *Journal of Urban Economics*, 15, 317-326.

DiPasquale, D. and C. T. Somerville. 1995. “Do House Price Indexes Based on Transacting Units Represent the Entire Stock? Evidence from the American Housing Survey,” *Journal of Housing Economics*, 4, 195-229.

Downes, T.A. and J.E. Zabel. 2002. “The Impact of School Quality on House Prices: Chicago 1987-1991,” *Journal of Urban Economics*, 52, 1-25.

Figlio, D.N. and M.E. Lucas. 2004. “What’s in a Grade? School Report Cards and House Prices.” *American Economic Review* 94(3), 591-604.

Gallant, A.R. 1981 “On the Bias in Flexible Functional Forms and an Essentially Unbiased Form: The Fourier Flexible Form,” *Journal of Econometrics*, 15, 211-245.

Gibbons, S. and S. Machin. 2003. “Valuing English Primary Schools,” *Journal of Urban Economics* 53, 197-219.

Gill, H. L. 1983. Changes in City and Suburban House Prices During a Period of Expected School Desegregation,” *Southern Economic Journal*, 50 (1), 169-184.

Kane, Thomas J. and Douglas O. Staiger, 2002, “Volatility in School Test Scores: Implications for Test-Based Accountability Systems,”*Brookings Papers on Education Policy: 2002*, p. 235-283.

McMillen, D.P. 2003. “Neighborhood House Price Indexes in Chicago: A Fourier Repeat Sales Approach,” *Journal of Economic Geography*, 3(1): 57-73.

McMillen, D.P. and J. Dombrow. 2001. “A Flexible Fourier Approach to Repeat Sales Price Indexes,” *Real Estate Economics*, 29, 207-225.

Oates, W.E. 1969. “The effects of property taxes and local public spending on property values: An empirical study of tax capitalization and the Tiebout hypothesis. *Journal of Political Economy*, 77, 957-71.

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 fourth grade), and three secondary schools offering French Immersion. Students must apply for these schools and most, but not all, students are admitted. 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 ratings the past five years. Annual tuition at these four schools is in the $10,000 to $15,000 range. There are a few other private schools in addition to these four. There are also Catholic, Christian, Muslim, and Jewish parochial schools, though only the Catholic schools are of size.

A cheaper option is to apply for cross-boundary admission to a good public school. Unfortunately, the Vancouver School Board 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 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 to East Vancouver. The discussion was complicated by the fact that secondary schools have special programs in certain fields (e.g., 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-Principle, 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.