

# **Does a New Rail Rapid Transit Line Announcement Affect Various Commercial Property Prices Differently?**

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**Abstract:** An announcement of new rail rapid transit access to urban commercial centers may lead to greater business activity and agglomeration economies, while causing anticipation of construction disruption and resource diversion away from other infrastructure. Using a rail rapid transit line announcement in Vancouver, BC, Canada, we estimate the net capitalization effect for each individual commercial property price resulting from expected improved urban center access. We focus on 1,895 repeat sales straddling this announcement date and use a nonparametric estimation technique - Locally Weighted Regressions - to estimate how travel time changes to the Richmond, BC and Vancouver, BC central business districts, the Olympic Village, and Vancouver International Airport affect various commercial property prices differently. By differencing our estimation equation over the two periods of the repeat sales, the time-invariant variables drop out and we are left with the travel time savings and the difference in temporal fixed effects as regressors. We find travel time savings' marginal effects on property values can be positive or negative, and patterns vary dramatically across commercial land use types and locations. Falsification and balancing tests validate our findings.

**Keywords:** Locally Weighted Regressions; nonparametric estimation; rail rapid transit; commercial property values

**JEL Codes:** R3, R4

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## Introduction and Literature Review

Transportation and access to urban centres has long been a central focus of urban economics (Alonso, 1964; Muth, 1969). More recently, agglomeration economies (Duranton and Puga, 2004; Puga, 2010) – which can facilitate labor market clearing with larger pools of workers - have received substantial attention as an explanation of the development of urban areas. Additional congestion of roads and highways often occurs together with agglomeration and growth. Rail rapid transit is one way for workers and employers to “connect” in urban areas while avoiding much of the road traffic. An announcement of new rail rapid transit access to urban commercial centers may lead to greater business activity and agglomeration economies, while causing anticipation of construction disruption, higher taxes, and resource diversion away from other infrastructure. In addition, while transit can alleviate some of the additional congestion due to growth, there may still be an increase in congestion overall if a city grows sufficiently. Thus, *a priori*, the expected net impact of the announcement on individual commercial property values could be positive or negative. Using a new rail rapid transit line announcement in Vancouver, BC, Canada, we estimate the net capitalization effect for each individual commercial property price resulting from expectations of improved urban center access. We allow for the possibility that the net effect can enhance some commercial property values and lower others.

Our analysis is based on the notion that access to employees in urban areas can be key drivers of commercial property values and economic growth (O’Sullivan, 2009). Many city centres and subcentres are hubs for economic activity. Rail access to and from these centres, where people engage in business transactions (such as shopping or air travel, etc.), can encourage the most productive workers to agglomerate and live in neighborhoods in other parts of the city

near their jobs, where their commute times to work would be low (Fu and Ross, 2013) but their travel time to the centres would also be relatively low. Assuming individuals wish to minimize their travel costs for transactions in the city centres (such as shopping, services, air travel, etc.), they may benefit from living close to their jobs while having better access to the city centres. When workers cluster in neighborhoods with improved transportation access to the centres, the large concentrations of workers outside the centres can lead to agglomeration economies for firms due to labor market pooling. Agglomeration economies can lower operating costs, so that these lower costs become capitalized into commercial property values.

At the same time, expectations of greater congestion due to higher consumer traffic associated with growth, and/or the disruption of businesses due to construction of transit infrastructure (Fershau, 2003), may have negative effects on commercial property values following an “announcement” of new transit service. For instance, Diao et al (2015) note that job growth associated with public infrastructure (such as rail) can also lead to congestion on access roads, which may detrimentally impact businesses and make their property locations less desirable. Also, funding for new transit can divert resources away from roads and may possibly detrimentally impact the desirability for some businesses to locate in those neighborhoods (Fershau, 2003).

These contrasting forces may lead businesses, policy makers, and others to pose the questions: what are the effects of a new rail rapid transit line announcement on commercial property values? And, are the effects different at various locations throughout a city? Answering these questions are key objectives of our research.

In more general settings, there are many studies examining the impacts of transportation infrastructure on property values, such as Duranton and Turner (2011), Anderson (2014), and

Bauernschuster et al (2017), who focus on the relationship between transit and road usage or congestion. Few known previous studies, however, focus on the nexus of commercial property impacts<sup>1,2</sup> from proximity to specific business centers in two cities in the region, surrounding an announcement of a new rail rapid transit line.

Much of the work in this area focuses on hedonic housing price models, and to a smaller extent, commercial property impacts of transit. There is also a strand of literature with a focus on transit's impact on property values. The focus of Baum-Snow and Kahn (2005) is on the use of transit to access the central business district (CBD) in a monocentric city model. There are also some recent studies of the impacts of increased public transit on road usage, including Duranton and Turner (2011), who find there is mixed evidence in terms of the direction and significance of these effects.

In the earlier literature, Damm (1980) studies the response of property values of single and multiple family houses and retail properties in anticipation of the heavy rail transit system installation in Washington D.C. The structural approach represents buyers' and sellers' behavior. Their second estimation equation uses prices as the dependent variable. They find that for multi-family properties, the closer the property is to the metro station, the lower the property value but the effect of distance declines rapidly. Retail property is much more sensitive to distance to the metro stations.

Kim and Zhang (2005) assess whether the benefits of the station are the same in other parts of the same metropolitan area, using 731 properties in the metropolitan area of Seoul, South Korea. They assess the question of how and where (in terms of distance) does the transit station

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<sup>1</sup> The lack of research on commercial property value impacts of airports was pointed out to us by Jan Brueckner.

<sup>2</sup> Since airport noise and other noise is less of a concern for commercial property, the focus for commercial property studies is more properly placed on the benefits from proximity to the various employment centres.

impact land values. One of the paper's conclusions is that the closer the property's location to the station and the denser the surrounding area, the higher the price will be for commercial land values.

Landis et al (1995) examines 5 transit systems in California. The paper compares transit investments, land uses and property values of single family property, commercial property, station area and metropolitan areas. The main research question is whether urban rail transit investments affect nearby property values and land uses. They conclude that it does but the effect is small, is not consistent, and not always in directions that are expected.

Debrezion (2007) measures the impact of railway stations on property values by analyzing several other previously published studies in a meta-analysis. The paper finds variation in these other studies, in terms of the differences in the impacts on residential and commercial property and the impact's dependence on demographic factors. The analysis concludes that the other studies' findings are not uniform and tend to be overestimated.

Redfearn (2009) focuses on a new rail line in Los Angeles, CA, and finds that there are important spatial variations. The results of this study include that there are no significant effects of a rail line on residential property values, after considering spatial variations.

There has been relatively little known research on the impact of access on commercial property values focusing on the announcement of rail rapid transit.<sup>3</sup> Billings (2011) studies a rail transit announcement in Charlotte, NC and finds residential neighborhood price impacts ranging from 4% to 11%, while he finds no significant impacts for commercial properties. His analysis is based on estimating a hedonic model using a difference-in-differences approach to identify the

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<sup>3</sup> This lack of existing research on the commercial property impacts – and the economic motivation of agglomeration due to the ability of workers to cluster in neighborhoods throughout a city with the advent of faster travel times - are the major reasons we focus on commercial properties.

effects. Knapp et al (2001) study whether announcements of plans impact land values in several U.S. cities. They find that “plans to invest in transportation infrastructure can affect property values even before the infrastructure is in place”. Also, McMillen and McDonald (2004) study the impacts on residential property values of a new rail rapid transit line in Chicago in the 1980’s and 1990’s. One of their major findings is that prices started to react to the plans of the rail line, before the line is completed.

Some of the previously discussed studies, such as Billings (2011), consider a difference-in-differences approach to estimating the effect of an announcement. In a somewhat different context, Ries and Somerville (2010) study the effect of a rezoning announcement and school quality in Vancouver, BC Canada. As their application is based on residential properties, they start with a traditional hedonic model with the log of sale price as the dependent variable, and independent variables including the neighborhood price index at a particular time, the property characteristics, the average neighborhood test scores, and other neighborhood characteristics. Taking the two sales of any particular property, and differencing these in the model, the property characteristics and “other” neighborhood characteristics terms drop out. This leaves the log of the sale price ratio as the dependent variable, and explanatory variables for the neighborhood price changes between the two sale dates, and the difference in neighborhood school test scores. In estimating their model, they focus on the impacts of changes in test scores for repeat sales of properties that straddle the date of the rezoning announcement, while controlling for a repeat sales price index. They later perform falsification tests, as an approach to validate their estimates. Although these authors estimate a least squares model, their framework is amenable to a nonparametric approach, such as LWR, in order to allow for the possibilities of nonlinearities in

the relationship between the change in the variable of interest and the change in the property values. We implement this type of a nonparametric approach in our analysis.

Given the array of findings in previous studies in terms of the magnitudes and directions of the effect of rail, this underscores the importance of a framework that considers spatial variation based on the locations of individual properties. This motivates our empirical approach of examining spatial heterogeneity in the context of an announcement.

In the present paper we focus on a major Canadian metropolitan area, Vancouver, BC, and we motivate our analysis by analyzing the impacts of enhanced access to four prominent and quite distinct business districts within the metropolitan area. These include the main central business district (CBD) of the metro area (Vancouver City Centre); a suburban business centre (in Richmond, BC); a nascent business centre (the Olympic Village area in Vancouver); and Vancouver International Airport (YVR).

We estimate a nonparametric empirical model, which allows for the possibility of heterogeneity in the signs and magnitudes of these impacts on commercial property values, using the announcement of a new rail rapid transit line as part of our estimation approach. We analyze data on sale prices for 1,895 commercial properties that experienced repeat sales in Vancouver and Richmond over the period of 1995 to 2016. These repeat sales observations have sale dates that straddle the date of the Canada Line announcement. We examine the issue of whether lower travel time between a particular commercial property and each of these 4 employment centres led to changes in the property's sale price (while controlling for general price changes with time

fixed effects).<sup>4</sup> We estimate the model using Locally Weighted Regressions<sup>5</sup> (LWR), which allows for the possibility that various properties are affected differently across geographic space. We find that expected travel time changes between commercial properties in the Cities of Vancouver and Richmond and each of the 4 urban centres as a result of the Canada Line announcement led to increases in the sale prices of some commercial properties and decreases in sale prices of other commercial properties. These results vary by industry and by geographic location of the properties, and we demonstrate their patterns with maps and figures of the marginal effects. Our falsification and balancing tests validate our findings. Our focus on the relatively under-studied commercial property impacts of a rail rapid transit announcement, along with the nonparametric approach that allows for marginal effects which can vary across locations, are some of the contributions of our analysis that we present in more detail below.

The remainder of this paper is organized as follows. First, we provide some background on Metro Vancouver and the Canada Line. Then we describe the details of our specific problem and of our approach. Next we provide an explanation of the data, followed by an exposition and interpretation of the results. Finally, we discuss our conclusions and some policy implications of these results.

### **Background on Metro Vancouver, BC and the Canada Line**

On June 24, 1998, there was a “surprise announcement”<sup>6</sup> that the Canada Line (an elevated rail rapid transit line) would be built, connecting the Richmond CBD with YVR, the

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<sup>4</sup> Following the approach of McMillen and Dumbrow (2001), we also experimented with a Fourier repeat sales price index. The Fourier approach is based on a “smoothing” technique that leverages variation across time periods of sales. However, many of our resulting regression estimates with the Fourier index are implausible, so we decided to utilize the time fixed effects.

<sup>5</sup> McMillen and Redfearn (2010) indicate that Geographically Weighted Regressions (GWR) is a special case of Locally Weighted Regressions (LWR). Therefore, in this paper we refer to our estimation procedure as LWR, except when referring to the GWR routine in Stata.

<sup>6</sup> “SkyTrain Line to Airport Proposed”, *Vancouver Sun*, June 25, 1998.

Olympic Village, and Vancouver CBD. The Canada Line is an automated, grade-separated rail rapid transit line with a day-time of 20 trains per hour (every three minutes) on the trunk line and 10 trains per hour (every six minutes) on the two branches to the airport and Richmond CBD. A map of the Canada Line stations is in Figure 1. As a part of the announcement, it was stated that a goal was to move quickly with construction, in part in order to help lure the 2010 Olympics to the city. Our objective is to determine how commercial property values were affected by expected changes in travel time between these four business centres and commercial properties throughout Richmond and Vancouver, as a result of this announcement.

A priori, the direction of the effect of changes in anticipated travel time to these landmarks on commercial property values in the Cities of Vancouver and Richmond is unknown. The direction of this effect (positive or negative) is expected to depend on the locations of each commercial property and the actual land use at each location. Both possibilities (positive and negative effects) are generally consistent with some of the findings of Duranton and Turner (2011) that adding public transit in a metropolitan area can have positive, negative, or no significant effects on road usage.

In considering the importance of worker access to and from Vancouver CBD, Richmond CBD, the Olympic Village, and YVR, some statistics about the prominence of the metro-area are worthy of discussion. According to Statistics Canada, the total population of Metro-Vancouver was approximately 2.3 million in 2011, which represented a 9.3% rise over the previous 5 year period (compared with a 5.9% rise nationally).<sup>7</sup> There were 1.36 million people employed in the metro area in June 2016, with an unemployment rate of 5.4%.<sup>8</sup> The Vancouver CBD is the major

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<sup>7</sup> <https://www12.statcan.gc.ca/census-recensement/2011/as-sa/fogs-spg/Facts-cma-eng.cfm?LANG=Eng&GK=CMA&GC=933> ; accessed July 26, 2016.

<sup>8</sup> <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/lfss031-eng.htm> ; accessed July 26, 2016.

employment center of the metropolitan area. In 2012, Vancouver International Airport (YVR) – which is located in Richmond, BC - served 17.6 million enplaned-deplaned passengers of which 9.2 million were domestic passengers and 8.4 million were international passengers. 227,000 tonnes of cargo were enplaned and deplaned at YVR in 2012. Overall, 49% of global Gross Domestic Product (GDP) is accessible by daily, non-stop scheduled air service from YVR. The airport also has the most scheduled flights to China of any airport in North America and considerably more on a per capita basis, which reflects Vancouver's and YVR's role as a North American gateway to Asia.<sup>9</sup> According to the Vancouver Airport Authority, there were approximately 23,600 direct jobs at the airport in 2013, in addition to many additional indirect and induced job opportunities. Clearly, the airport is an important employment hub in the metro-Vancouver area.

In July, 2003, Vancouver was officially awarded the 2010 Olympic Winter Games, in part due to its strong security plans, sports and other facilities and “Athletes’ Village”.<sup>10</sup> There were approximately 45,000 Olympics-related jobs created between 2003 and 2010, and 650,000 visitors came to British Columbia for the Olympics in 2010.<sup>11</sup> With the Canada Line opening in

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<sup>9</sup> In other unpublished research (available upon request) that utilizes OLS regressions of the sale price of commercial properties against distance to YVR and a “connectivity index”, we find the effect of distance to the airport effect is negative and significant, while the connectivity effect is positive and significant. These results, however, are not obtained through an identification strategy as we implement in the current paper. Also, the connectivity index estimate is identical for all property locations in a given year, and there is little variation in the connectivity index in the various years of our sample (which are the reasons why we do not include connectivity in our repeat sales model specification, in addition to the fact that differencing would lead these invariant connectivity effects to essentially drop out). Therefore, this lack of variation in connectivity over space in a given year and over time implies there is not a major shift in supply (or “supply effect”) for air travel, as Bilotkach et al (2012) have described. Thus, the changes in air travel due to announcement of the Canada Line can be considered a pure demand side effect if we find that the rail rapid transit announcement has a significant effect on commercial property values.

<sup>10</sup> <http://www.nytimes.com/2003/07/03/sports/olympics-vancouver-wins-2010-winter-olympics-by-3-vote-margin.html?pagewanted=all> ; accessed July 26, 2016.

<sup>11</sup> [http://www.huffingtonpost.ca/2011/10/27/vancouver-olympics-economic-benefit\\_n\\_1035427.html](http://www.huffingtonpost.ca/2011/10/27/vancouver-olympics-economic-benefit_n_1035427.html) ; accessed July 26, 2016.

late-2009, it was up and running before the Olympics, with a station at Olympic Village.<sup>12</sup> Part of the intention of including a Canada Line station at the Olympic Village was to accommodate some commercial demand that could not be met in the Vancouver CBD.<sup>13</sup>

Richmond-Brighouse station is located near the Richmond CBD, where there are many businesses, a hospital, and Richmond City Hall. Although improved access to the Brighouse area could benefit these businesses (and others throughout the metropolitan area), Fershau (2003) notes how there were plans for vehicle levies and funding diversion away from road infrastructure in order to finance the Canada Line. These fiscal issues could have detrimentally impacted businesses (and in turn, commercial property values) throughout Richmond and Vancouver following the Canada Line announcement.

For our empirical analysis, one goal is to determine how expected changes in travel time to/from these four urban centres, due to the rail rapid transit line announcement, were capitalized into commercial property values. There is some evidence in the prior literature that the direction of the impacts of transit on commercial property values may be non-linear. In the next section we outline a “theoretical” motivation for our empirical analysis, then we explain the details of our estimation strategy for testing how changes in travel times to various parts of the two cities affect various commercial real estate prices differently.

## **Approach**

Consider a city where the cost function of the typical firm depends on the stock of physical capital (a short-run fixed input); and the price of labor. The typical firm’s objective is to minimize costs, and its total costs fall if there are agglomeration economies due to workers

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<sup>12</sup> This station was not originally part of the plan for the Canada Line but the City of Vancouver decided to fund its construction to support the City’s goals to regenerate the area around it.

<sup>13</sup> City of Vancouver 2009 Metro Core Jobs and Economy Land Use Plan.

clustering at the given business location. Employers pay lower effective wages if employees locate close to the employer's location, due to lower commuting costs. We assume workers sometimes need to drive or walk to several business centres in the city to engage in personal transactions (e.g., shopping, banking, air travel, etc.). With the announcement of the rail line, residents anticipate that there may be ease of travel from their residential location near their place of work to the business centres, which enhances the desirability of living near the employer's location.<sup>14</sup> This results in larger clusters of residents living near their employers, and in turn, a larger pool of workers from which the employers may hire. At any given business location in the city where there is expectation of better access to various urban centres, these agglomeration economies (due to the lower transportation costs expected after the announcement of the rail line) that occur if they choose to reside near their employer's location will lower the effective wage that these workers need to be paid. Since the agglomeration economies end up reducing the effective wages that businesses pay these workers, these reduced business operating costs become capitalized into commercial property values at the particular locations near the clusters of workers. On the other hand, if the effects of expected congestion due to growth of the city, and construction disruption, more than offset the agglomeration economies benefits, it is possible that the firms' effective labor costs may increase. A goal of our empirical research is to estimate how changes in the expected travel times from a given location to one of Vancouver's 4

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<sup>14</sup> Even though the average travel times we report in Table 1 reflect a fall in travel time by rail compared with by car, a helpful referee suggested that travel time by rail may be higher than travel time by road for some individual businesses. Indeed, we agree that it is possible at some locations that travel time by rail is higher than travel time by car. In these individual instances, a negative sign on the travel time parameter estimate would imply that higher travel time leads to lower property values; if businesses cannot benefit from workers choosing to agglomerate due to easier access to the other business centres with rail, it is likely that these businesses are worse off because the effect of construction disruption, higher taxes, etc. dominates the travel time effects. However, since it is apparent in Figure 1 that on average, travel time by rail is lower than travel time by car, it is a reasonable assumption that the negative sign implies that for the average property owner, higher property values accompanied the lower travel time.

business centres, after versus before the announcement of the rail line, affects commercial property values at each given location. We examine empirically how these effects vary across different commercial property locations throughout the city.

Our nonparametric estimation strategy enables us to quantify the effect of improved access to the 4 urban centres on commercial property values by examining how travel time savings impact these property values differently at different locations. First, we follow the general estimation approach of Ries and Somerville (2010) and study the effects of travel time savings by analyzing repeat sales properties that sold once before and once after the rail rapid transit announcement. We include time fixed effects in our model by including a residual term that includes a fixed effect component and an iid component. Taking the two sales of any particular property, and differencing these in the model, the property characteristics and “other” neighborhood characteristics terms drop out. This leaves the log of the sale price ratio as the dependent variable, and the differences in travel times and the difference in the two fixed effects (as well as a new error term that only includes iid components).

Our empirical model is analogous to a hedonic housing model, except our problem is for commercial properties so it is somewhat different. Specifically, we first consider a linear model of the form:

$$\text{Log}(P_{nt}) = \mathbf{C}_{n,t}\boldsymbol{\theta} + \mathbf{X}_n\boldsymbol{\phi} + \varepsilon_{nt} \quad , n=1, 2, \dots, 1895; t=1995, 1996, \dots, 2016. \quad (1)$$

where  $\varepsilon_{nt} = \tau_t + \upsilon_{nt}$ ,  $\upsilon_{nt} \sim \text{iid}(0, \sigma^2 \mathbf{I})$ ;  $P_{nt}$  is a  $N$  by 1 vector of the actual sale price of property  $n$  in time  $t$ ;  $\mathbf{C}_{n,t}$  (with 4 by 1 parameter vector  $\boldsymbol{\theta}$ ) is a  $N$  by 4 matrix of the travel time from commercial property  $n$  to four business centres at time  $t$ ;  $\tau_t$  is a  $N$  by 1 vector of metro-area wide fixed effect for properties that sold in year  $t$ ;  $\mathbf{I}$  is the identity matrix (with dimension  $N$  by  $N$ );  $\mathbf{X}_n$  (with  $m$  by 1 parameter vector  $\boldsymbol{\phi}$ , where  $m$  is the number of explanatory variables in  $\mathbf{X}_n$ )

is a matrix of time-invariant observations for physical characteristics of the commercial property (such as the actual year of construction, gross building area, and lot size).  $X_n$  includes a column of 1's as an intercept term as one of the explanatory variables in the characteristics matrix. The subscript  $n$  is the observation number that is comprised by the repeat sales property pairs.

A potential drawback of a repeat sales approach is that the quality of properties may change over time. An advantage of the data set we have obtained from BC Assessment is that there is some data on an “effective construction date” variable, which adjusts the construction date for any significant changes in quality.<sup>15</sup> Moreover, among all of the repeat sales properties in our sample for which we have “effective construction date” information, this effective date is the same for both sales observations, implying no significant quality changes for these repeat sale properties between sales during the time period of 1995-2016. Also, all of the 1,895 repeat property sales pairs in this period only include “qualified” or arm’s-length sales, so there is no concern with any “zero” sales prices.

Our estimation strategy focuses on the announcement date of the Canada Line (June 24, 1998). We examine the change in travel time, before versus after the announcement, between commercial properties in Richmond and Vancouver and the four prominent business districts—Vancouver International Airport, the Olympic Village, the CBD of Vancouver, and Brighthouse Station in Richmond. Assuming expected travel time to these landmarks is different before and after the announcement of the rail rapid transit (that is, any capitalization of future travel time

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<sup>15</sup> For instance, Landcor.com/support defines the case when the “effective year” is different from the “year built” as an indication “that a major renovation or addition has taken place and the year built no longer reflects the age or condition of the building.” Among the 1,895 repeat sales properties that straddle the 1998 announcement, there are approximately 250 for which we have information about their “effective year”. Since there is no change in the “effective year” variable between the two sale year observations in this 250 observation sub-sample, this is evidence that there was likely no major quality change occurring in the properties during the period of our sample.

savings occurs immediately), as well as differencing equation (1) for the two periods of a given property's repeat sale that straddle the announcement of the rail line, yields:

$$\text{Log}(P_{n,t+j}/P_{nt}) = (\mathbf{C}_{n,t+j} - \mathbf{C}_{n,t})\boldsymbol{\theta} + \tau_{t+j} - \tau_t + v_{n,t+j} - v_{nt} \quad (2)$$

where  $v_{nt} \sim \text{iid}(0, \sigma^2 \mathbf{I})$ , and  $(\mathbf{C}_{n,t+j} - \mathbf{C}_{n,t})$  is a N by 4 matrix of travel time differences for the 4 “landmarks”, and  $\boldsymbol{\theta}$  is a 4 by 1 vector. The matrix  $(\mathbf{C}_{n,t+j} - \mathbf{C}_{n,t})$  represents the difference in travel time to each landmark from commercial property n before the announcement (time t) and after the announcement (time t+j), including time to reach the nearest station and the time to ride the train to the landmark. The term  $\tau_{t+j} - \tau_t$  represents a vector of new regressors (each with elements equal to 1 if a sale occurred in time t+j, -1 if a sale occurred in time t, and 0 otherwise).

After generating the regressors for  $\tau_{t+j} - \tau_t$ , we could use OLS to regress the independent effects of changes in sale prices on  $\tau_{t+j} - \tau_t$  and the 4 time change variables in Richmond and Vancouver, as in (2).

But a potential limitation of using OLS to estimate this model (2) is that our motivation described in the introduction section, and the results in the previous literature, imply there may be at least 2 possible effects of the Canada Line announcement. One effect is the anticipation of easier access to job opportunities from their employment location to these 4 landmarks that encourages residents to live near their employment location, which in turn creates potential agglomeration economies near some or all of the 16 Canada Line stops. The opposite effect could result from potential disruption due to construction, diversion of funds away from road construction (which can harm businesses that ship their goods), and additional road congestion due to the economic growth in these neighborhoods. One way to allow for this potential variation is with LWR, as in McMillen and Redfearn (2010), which we use to generate separate estimates

for the parameter  $\theta$  that are computed for various target points ( $n$ ). In this analysis, the target points are the locations of the repeat sales.

Specifically, with our nonparametric approach, consider the following, more general variation of model (1):

$$\text{Log}(P_{nt}) = f(\mathbf{C}_{n,t}, \mathbf{X}_n, \tau_t) + \upsilon_{nt} \quad (3)$$

where  $\upsilon_{nt} \sim \text{iid}(0, \sigma^2 \mathbf{I})$ . Differencing between the two periods of the repeat sales, and rearranging, yields:

$$\text{Log}(P_{n,t+j} / P_{nt}) = f(\mathbf{C}_{n,t+j}, \mathbf{X}_n, \tau_{t+j}) - f(\mathbf{C}_{n,t}, \mathbf{X}_n, \tau_t) + \upsilon_{n,t+j} - \upsilon_{nt} \quad (4)$$

McMillen and Redfearn (2010) note that nonparametric estimation of a nonlinear function by LWR can be accomplished by estimating weighted least squares. In other words, in the context of our problem, (3) becomes:

$$w_{nk} \text{Log}(P_{nt}) = w_{nk}(\mathbf{C}_{n,t})\boldsymbol{\theta}_n + w_{nk}\mathbf{X}_n\boldsymbol{\phi}_n + w_{nk}(\tau_t)\boldsymbol{\gamma}_n + \upsilon_{nt} \quad (3')$$

where the elements of  $w_{nk}$  are defined as the kernel weights,  $(\exp(-(d_{nk}/b)^2))^{1/2}$ ;  $b$  is the bandwidth (a scalar);  $d_{nk}$  is the distance between properties  $n$  and  $k$ ;  $\boldsymbol{\theta}_n$  is an  $N$  by 4 matrix of parameters;  $\boldsymbol{\phi}_n$  is an  $N$  by  $m$  matrix of parameters (where  $m$  is the number of explanatory variables, i.e., columns, in  $\mathbf{X}_n$ ); and  $\boldsymbol{\gamma}_n$  is an  $N$  by 1 vector of parameters. We know  $\mathbf{X}_n$  is time invariant. This time invariance, together with (3'), implies that estimation of (4) by LWR is equivalent to estimating the following by least squares, once for each observation (target point),  $n$ :

$$w_{nk} \text{Log}(P_{n,t+j} / P_{nt}) = w_{nk}(\mathbf{C}_{n,t+j} - \mathbf{C}_{n,t})\boldsymbol{\theta}_n + w_{nk}(\tau_{t+j} - \tau_t)\boldsymbol{\gamma}_n + \upsilon_{n,t+j} - \upsilon_{nt} \quad (5)$$

An important issue to consider is bandwidth selection, since McMillen and Redfearn (2010) note that LWR results can be sensitive to the choice of bandwidth. With the Gaussian kernel weights (which is the kernel that we utilize in estimation of the LWR of model (5)), the

bandwidth determines how “flat” the distribution is for the weights and the tail thickness, and how concentrated the weights are around the mean. We use the “GWR” routine in Stata to estimate (5), which calculates the optimal bandwidth with a cross-validation procedure.<sup>16</sup>

In the results section below, the varying signs and magnitude of the LWR marginal effects estimates  $\theta_n$  demonstrate that there are nonlinearities in the  $f(\bullet)$  relationships, and if we were to estimate equation (2) by OLS this would mask the true effects of changes in travel time on commercial property values. This is justification for estimating separate equations for individual observations, since we find evidence that there are different parameter estimates for the travel time savings across the sample. We also demonstrate with some graphical plots of the marginal effects below that properties in some industries tend to have higher marginal effects with respect to some landmarks, on average, while those in other industries tend to have higher marginal effects with respect to other landmarks.

## Data

The data and variables are as follows. A key variable is the sale price of commercial properties in Richmond BC and Vancouver BC. Our commercial property sales data (purchased from Landcor) are from the BC Assessment Authority for sales in the years 1995-2016, for the full set of 1,895 “qualified” commercial property repeat sales transactions in Vancouver and Richmond, the cities through which the Canada Line runs.

Our control variables include the “effective” construction year (the average of which is 1995), which adjusts the actual construction date for any known improvements;<sup>17</sup> actual “year

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<sup>16</sup> A helpful editor of this journal noted that Stata’s GWR procedure usually tries to produce good predictions for the dependent variable, and the optimal bandwidth tends to be larger when the focus is on marginal effects. But since our marginal effects graphs do not look particularly noisy, this may not be an important issue in our particular application.

<sup>17</sup> It is noteworthy that we have data on approximately 250 of the 1,895 repeat sales pairs in Vancouver and Richmond for which the “effective year” data and “year built” data are available. In our sample of repeat sales, the

built”; square footage; gross building area; and the travel times from each commercial property to each of the Canada Line stops at four business districts: Vancouver International Airport, the Olympic Village, Vancouver CBD (Vancouver City Centre station), and Richmond CBD (Brighthouse Station).

We generate the data on travel time from each of the 1,895 repeat sales pairs of commercial properties in Vancouver and Richmond to each of the 4 urban landmarks as follows.<sup>18</sup> There are 16 total Canada Line stations, which are located in Richmond and Vancouver. We assume that residents choose to live near some commercial properties to be close to their jobs, and may commute to one of the 4 landmarks for personal transactions. For commercial properties that are less than 400 metres walking distance to the nearest station, we assume individuals can walk from those properties to the nearest station (or from the nearest station to those properties). For commercial properties greater than 400 metres away from the nearest station, we assume individuals can drive (or take a bus, taxi or uber) to the nearest station.<sup>19</sup> Once at the nearest station, individuals can take the Canada Line from that station to

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effective construction year is the same for both sales in all of the repeat sales pairs. In each of 250 of these repeat sales pairs, the first “effective year” observation is the same as the second “effective year” observation, implying no major renovations occurred between the two sales. Additionally, we run some OLS regressions of the model (2) using this sample of 250 observations, but also including the difference between the effective year and the year built variables as an additional explanatory variable. We find that the coefficient on the term (year built – effective year) is statistically insignificant. For these reason, together with the fact that we only have “effective year” data for approximately 15% of the repeat sales that straddle the announcement date, we are confident about excluding the “effective year” change from our model.

<sup>18</sup> We use the `osrmtime` routine in Stata (developed by Huber and Rust, 2015) to generate the drive distance, drive time, walk distance, and walk time from each of the 1,895 commercial properties to the nearest of the 16 Canada Line stations. These travel times are based on actual drive time by car during a rush-hour period in June, 2016. The travel times by Canada Line from each of the 16 stations to each of the 4 landmark stations (YVR, Olympic Village, Vancouver CBD, and Brighthouse/Richmond) are obtained from Translink; see [http://www.translink.ca/-/media/Documents/schedules\\_and\\_maps/travel\\_times/skytrain\\_schedule\\_between\\_stops\\_canada\\_line.pdf](http://www.translink.ca/-/media/Documents/schedules_and_maps/travel_times/skytrain_schedule_between_stops_canada_line.pdf) (accessed July 6, 2016).

<sup>19</sup> In general, there are several different possibilities for how people may reach the 4 business centres. We focus on the subset of people who drove before the announcement, and then after the announcement they expected to get to the nearest Canada Line station by some ground mode (car, taxi/uber, or bus) and take the Canada Line to the business centres. We assume that on average, the speeds of these various ground modes are approximately the same, given that there is the need to find parking when one drives, and generally there are waiting times involved for taxis and busses.

one of the 4 “landmark” stations: Vancouver International Airport, Olympic Village, Vancouver CBD, and Brighthouse-Richmond. Similarly, people can travel in the other direction (from the landmark to the station nearest to a particular commercial property, then walk or take a taxi to a particular property to engage in business activity). We calculate the total travel times from each of the repeat sale 1,895 commercial properties to each of these 4 Canada Line stops, and compare these with the drive time from each commercial property to each of these 4 “landmark” points. The difference between each of these 4 terms are included as the 4 travel time savings explanatory variables in equation (2) above.

Descriptive statistics of the data are presented in Table 1. For the sample of 1,895 repeat sales, the average travel time saving to Brighthouse is nearly 15 minutes; the time savings to the Vancouver CBD is approximately 3 minutes; travelers save approximately 5 minutes per trip to the Olympic Village; and they save about 13 minutes travelling to the airport.<sup>20</sup> The average of the natural log of the sale price ratio between each repeat sale pair is approximately 0.07 (which equals approximately 1.073 in levels). The average “effective year” is 1977, and the average actual “year built” is 1964.<sup>21</sup>

## Results

The estimation results for the model in differences for the two sets of repeat sales – estimation of equation (2) above – are presented in Table 2. In this specification, the intercept,

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<sup>20</sup> For individuals who drive to the airport, there is the additional time needed to find parking (which could be offsite), then get from the parking lot to the terminal. We do not have any concrete information on the time it takes passengers to get from the parking facilities to the YVR terminal, since there are many possible parking options for people who drive. The rail rapid transit drops passengers directly at the terminal. Also, as described above, for rail passengers who work less than 400 metres from the nearest rail rapid transit station we assume they walk to the station (and we consider this time as part of their total trip time when we estimate our empirical models), and we also consider the drive time (by car or taxi) from the business location to the nearest rail line station for passengers who are greater than 400 metres from the rail line.

<sup>21</sup> There are only 250 repeat sales pairs that straddle the announcement date for the period 1995-2016 in Vancouver and Richmond for which we also have data on “effective year” and “year built”.

and the other time-invariant variables in  $X$  are not included because they drop out when differencing equation (1) as we move to equation (2). But we end up with a new fixed effects term for each observation. The coefficient on the travel time savings ( $\theta$ ) to Vancouver City Centre is negative and significant, implying a one minute decrease in travel time leads to a two percent rise in commercial property values, on average. For the travel time to the Olympic Village, the sign of  $\theta$  is positive, and the magnitude implies a one minute increase in expected travel time leads to a two percent fall in commercial property values, on average. The positive sign of this coefficient is a potential indication that on average, the disruption effects and/or funding diversion from other modes that many business owners expected with the construction of the Canada Line (Fershau, 2003) may have dominated the travel time savings agglomeration effects for travel to the Olympic Village. The parameter estimates on travel time savings to YVR and travel time savings to Brighthouse are statistically insignificant. In the case of YVR this may be because the daily volume of trips between a given property and the airport is usually small. We also conduct a test for “spatial nonstationarity” on the OLS model with the Stata “GWR” routine (results are available from the authors upon request), and find that all of the explanatory variables (including the year of sale fixed effects) explain the dependent variable better with the GWR model than the OLS model, so we proceed with discussion of the GWR results.<sup>22</sup>

We first present the range of parameter estimates ( $\theta_n$ ) for each of the 4 travel time savings variable coefficients, in Tables 3, 4, 5, and 6. Travel time savings to the two city centres – Brighthouse (for Richmond CBD) and Vancouver City Centre (for Vancouver CBD) – had the greatest numbers of the 1,895 properties in the metro area that benefitted from the announcement

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<sup>22</sup> If the true relationship had been linear, we would find all  $\theta_n$  coefficients equal to each other in the LWR specification. With the spatial nonstationarity test, we strongly reject the hypothesis that all  $\theta_n$ ,  $n=1,2,\dots,1895$ , are equal to each other for each travel time savings variable.

of rail service. For the Brighthouse coefficients, nearly 85% of the 1,895 repeat sales coefficients are negative. This implies that for roughly 85% of these 1,895 properties, enhanced travel to/from the Brighthouse section of Richmond due to the expectation and/or presence of new rail rapid transit service led to higher property values. The magnitudes of the negative estimates of  $\theta_n$  range between -0.215 and 0.

The impacts of the announcement were also very beneficial with respect to travel time savings effects to/from the Vancouver CBD on property value changes throughout Vancouver and Richmond. For travel savings to this area, there were approximately 75% of the 1,895 commercial properties in Vancouver and Richmond with negative coefficients (that is, prices increased due to expected travel time savings). The range of negative values of  $\theta_n$  was between -0.42 and 0. The majority of the positive values of  $\theta_n$  are small (between approximately 0.03 and 0), implying those properties experienced small price declines due to the expectations of travel time savings - again, perhaps due to construction disruptions or concerns about diversion of funds from roads or other public services, and/or expectations of higher taxes to fund the rail rapid transit. Also, another possible explanation for the “small” estimates is that not all travelers switch from driving to rail, so those workers who continue to drive to their destination do not reap the travel time savings from riding the Canada Line.

The impacts of the announcement had primarily a detrimental effect for expected travel time savings to the Olympic Village, with nearly 74% of the 1,895 properties'  $\theta_n$  coefficients positive in Vancouver and Richmond. The vast majority of the positive  $\theta_n$  coefficients were small (between 0 and 0.06).

Somewhat surprisingly, the overall situation is more mixed for expected travel time savings to YVR, with approximately 69% positive  $\theta_n$  coefficients among the 1,895 commercial

properties in Vancouver and Richmond. But the negative  $\theta_n$  coefficients (with a minimum of -0.35) are substantially larger in absolute value than the positive  $\theta_n$  coefficients (maximum of 0.08), implying that there are some properties that benefit dramatically from improved access to YVR.

An interesting question is whether some locations benefit at the expense of others in terms of changes in marginal effects for one location when the marginal effects for another location changes. We plot all pairs of marginal effects ( $\theta_n$ ) in Figure 2. It can be seen that there is a negative relationship between the  $\theta_n$  for Vancouver City Centre and each of the other locations'  $\theta_n$  coefficients. In other words, as we examine properties for which the marginal effects for Vancouver City Centre travel time savings increase, we see the  $\theta_n$  for these same properties for travel to YVR, Brighthouse, and the Olympic Village decrease. Properties in Vancouver and Richmond may benefit by access to the CBD, but these benefits may come at the “expense” of the benefits of access to the other landmark locations. There may have been greater construction disruption in these other 3 locations at the time of the second sale of many of the 1,895 properties, but the disruption in CBD may have been relatively small compared with the access benefits because the CBD stations were underground while the stations in Richmond and YVR were above ground. In contrast, the  $\theta_n$  for travel time savings to YVR, the Olympic Village, and Brighthouse all tend to move in the same directions. For travel to these landmarks, as the travel time savings marginal effects for a particular property increase (i.e. become more negative) for travel to one of these landmarks, they also increase (i.e., become more negative) for one of these other landmarks. Enhanced access to one location (Brighthouse, YVR, or Olympic Village) that increases a property's value has a similar effect on the same property when there is faster travel to another one of these 3 landmark locations.

In order to dig deeper in terms of the geographic variation in the marginal effects for travel time change to each landmark, we plot the distance from each landmark against the marginal effects ( $\theta_n$ ). These plots are for each of the four most common “actual land use” categories for which we have data: retail stores<sup>23</sup>, storage facilities, hotel properties and strata properties<sup>24</sup>. An important consideration here is also the relative trip generation characteristics of the land uses. Trip generation is the number of vehicle trips between an origin and destination zone. Table 7 shows how trip generation per square foot of gross land area (GLA) varies across various land use types. We would expect to see greater impacts on land uses that generate a higher number of vehicle trips per unit of area. We also present maps of the Vancouver metro area, showing the negative coefficients (in green) and the positive coefficients (in red) for the effects of expected travel time changes on price changes.

We present the plots in Figure 3a for Brighthouse, and the coefficient maps in Figure 3b. In Figure 3a, it is apparent that the vast majority of hotel properties in Vancouver and Richmond experienced higher property values due to anticipation of faster and more reliable travel time to Brighthouse station with the Canada Line announcement. While the vast majority of “stores” properties are located between 10 and 20 kilometres from Brighthouse, most of these marginal effects are also negative, implying faster and more reliable access to Brighthouse from these properties led to higher values for these properties. For “storage” properties, there do not appear to be any clear patterns in the magnitudes of the marginal effects ( $\theta_n$ ) as distance to Brighthouse increases. For commercial “strata” properties, there are many approximately 8 kilometres from

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<sup>23</sup> In the sample of properties, most of the retail stores are “Mom and Pop” operations serving the immediate neighbourhood with either offices or a residence above them.

<sup>24</sup> “Strata properties” really refers to form of ownership, for example, compared to “rental” and included in this category are a variety of commercial uses, predominantly one or two story offices, warehouses and light industrial uses.

Brighthouse with marginal effects that imply very large price increases resulting from the Canada Line announcement. Overall, there are many commercial strata properties that benefit from the announcement. The map in Figure 3b shows that the vast majority of properties throughout the metro area benefit when expected travel times to Brighthouse fall.

For Vancouver City Centre, Figure 4a shows that virtually all hotel properties have primarily negative coefficients (although it turns out that these properties are generally the same ones that are “far” from Brighthouse). These hotel properties benefit substantially from easier access to the CBD. Also, the majority of stores have negative marginal effects ( $\theta_n$ ), and these effects are somewhat pronounced for properties that are relatively close to the CBD. In other words, these stores that are relatively “close” to the CBD tend to benefit substantially from faster and more reliable access to/from CBD. Also, the map in Figure 4b exhibits the vast majority of properties have negative coefficients. But the properties that experience price declines with better expected access to the City Centre are those far away in Richmond, right along the route of the Canada Line. Since the Canada Line is above ground in those locations, there was a substantial amount of disruption in those neighborhoods, as Fershau (2003) has noted. It is likely that the expected benefits from better access to Vancouver City Centre are more than offset by the anticipated nuisances from construction.

In contrast, the stores that are within six kilometres of the Olympic Village tend to face positive marginal effects (i.e., price decreases) as a result of the announcement of expected faster access to the Olympic Village. This may have been due in part to the construction disruption effects, as described by Fershau (2003), particularly because businesses may have expected a substantial amount of construction nearby (in addition to the Canada Line construction) during the period of 2003-2010 leading up to the 2010 Olympic Games. Retail is of course more

susceptible to construction disruption because shoppers have choices. But in Figure 5a, it is apparent that about half of the hotel properties were within 3 kilometres of the Olympic Village, and the majority of these had positive marginal effects. In fact, there is a negative trend between the marginal effects for hotels and the distance to the Olympic Village, as can be seen with the trend line in the hotels panel of Figure 5a. This implies that hotels further away from the Olympic Village benefitted relatively more with the expectation of faster access by rail. Once again, the majority of other commercial strata properties and storage had patterns that were less clear. In Figure 5b, it is clear that most of the properties that benefitted from expected improvements in access to the Olympic Village were those that were far away, and most nearby properties were worse off. As is evident in Figure 5b, most commercial properties in Vancouver experienced lower values accompanied by expected lower travel time to the Olympic Village, while the vast majority of properties that faced higher values after the announcement were far away from the Olympic Village (i.e., they were in Richmond).

Finally, perhaps the most intriguing actual use type for improved access to YVR is the commercial strata properties category. In Figure 6a, it is noteworthy that the majority of commercial strata properties within 10 kilometres of YVR had primarily negative marginal effects, but these  $\theta_n$  were relatively small. In contrast, beyond 10 kilometres, there are some strata properties with much lower values of the negative  $\theta_n$  (ranging as low as -0.3). There are also a small number of hotel property values that were close to YVR which suffer, likely due to the construction disruption effects (as described by Fershau, 2003), following the announcement. But there are also a few hotels within 6 kilometres away from YVR (and elsewhere in Richmond and Vancouver) that end up with the highest increases among all hotel property values after the announcement. Once again, the patterns for the other actual use types are somewhat less clear.

Similar to Vancouver City Center, most properties along the Canada Line route in Richmond were worse off after expectations of faster travel time to YVR, as can be seen in Figure 6b. Once again, this may be a result of the expected construction disruption right along the route of the Canada Line.

To demonstrate the effectiveness of our estimation approaches, we perform a “falsification test”, and a “balancing test” (similar to Bifulco et al, 2011). First, for the falsification test, we estimate equations (2) and (5), but for a different sample – this time we focus on properties that are “far” from Vancouver and Richmond (and the Canada Line), for an entirely different sample period of 1975-1994. We focus on the 293 repeat sales pairs in the City of Coquitlam, BC and City of Port Coquitlam, BC in an orthogonal time frame (i.e., between the years 1975-1994) to the main sample for Vancouver and Richmond (1995-2016). If there is a true “placebo effect” of the Canada Line announcement on properties that are far and that sold twice before the announcement, we would expect  $\theta$  (for each of the 4 landmarks in the OLS model) to be insignificant. Also, if the GWR bandwidth is insignificant, this is evidence that GWR performs no better than OLS, so GWR estimates would not be preferred to these insignificant OLS estimates. If this is the situation for the Coquitlam and Port Coquitlam sample, then these “placebo effects” would validate our results for the Vancouver and Richmond samples that straddle the Canada Line announcement date.

We present the falsification test estimation results in Table 8. The OLS parameter estimates for the four  $\theta$  are highly insignificant. Furthermore, the GWR bandwidth test has a P-value=1.000, which implies that GWR does no better than OLS for this sample. Given that the GWR bandwidth test was significant in the Vancouver and Richmond 1995-2016 sample, this is

strong evidence against spurious correlation in our primary GWR estimations for the Vancouver and Richmond sample that straddles the announcement date.

With the balancing test, we estimate the following model (6) for the Vancouver and Richmond sample from 1995-2016 including repeat sales that straddled the announcement date, in order to test for any remaining presence of reverse causality. We re-estimate this model 4 times, using the travel time change for each of the 4 landmarks as the dependent variables:

$$(C_{n,t+j} - C_{n,t}) = [\text{Log}(P_{n,t+j} / P_{nt})]\beta + \tau_{t+j} - \tau_t + \upsilon_{n,t+j} - \upsilon_{nt} \quad (6)$$

We demonstrate in Table 9 that  $\beta$  is insignificant in all 4 estimations. Therefore, the results of this balancing test provides strong evidence that we do not have reverse causality present in our model (5). Taken together, the falsification test and balancing test provide strong evidence that our estimation strategy for model (5) is sound.

## Conclusions

We examine the impacts of an announcement of new rail rapid transit – and the associated expected travel time changes to Vancouver CBD, Vancouver International Airport (YVR), the Olympic Village, and Richmond CBD - on commercial property sales prices over the period 1995-2016 throughout the cities that the Canada Line serves: Vancouver and Richmond, BC. Our nonparametric estimation approach enables us to demonstrate that some properties have higher value after the Canada Line announcement while others have lower value, after controlling for the evolution of prices over time. We confirm the validity of our results with falsification and balancing tests.

In general, the greatest number of properties saw their values rise with shorter travel time to the stations in the CBDs of the two cities – Vancouver City Centre and Brighthouse.

Expectations of faster and more reliable access to these centres enhances agglomeration economies by encouraging employees to work near their jobs in other parts of the city and make trips to the business centres for their personal transactions. These agglomeration economies may become capitalized into many commercial property values. Interestingly, the number of jobs (160,000) in the Vancouver CBD in 2011 was the greatest among these 4 business centres, while the number of jobs in Richmond CBD (38,500) in the same year was the second largest among the 4 business centres.<sup>25</sup> The expected faster access to these jobs from various points throughout the metro area may have made it easier for workers to cluster in areas outside of these two CBD's, which can imply greater agglomeration (and higher commercial property values) in those neighborhoods outside of these two cores. Also, the number of jobs in Downtown Vancouver rose by approximately 26%, the population in Downtown Vancouver rose by 75%, and the number of vehicles going in and out of this area fell by 20%, during the period 1996-2011 (according to the City of Vancouver). Despite the growing numbers of people living and working in the Vancouver CBD, this sharp decline in the number of vehicles in the CBD is anecdotal evidence to validate our assumption that more people are relying on the Canada Line to commute to their workplaces (both inside and outside of the CBD).

When parsing by actual use type, commercial strata properties nearest each of these four major business districts appear to rise in value substantially due to expectations of travel time savings after the announcement of construction of the Canada Line. There are also substantial effects for hotels that can be accessed more quickly to/from several of these four business districts. This reflects the high vehicle trip generation rate of hotels per unit of area relative to the other land use categories (as shown in Figure 7). Faster and more reliable access to hotels makes

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<sup>25</sup> Employment numbers are from Stats Canada.

these hotels more attractive for tourists and business travelers, which makes the locations of these hotels more valuable.

However, there are some locations in Vancouver and Richmond where expectations of travel time savings lead to a fall in property values after the announcement, which we attribute to the expectations of construction disruption, and possibly property owner concerns about funding being diverted away from roads, and/or expectations of higher taxes to finance the rail rapid transit (all of which has been documented by Fershau, 2003).

The marginal effects of travel time savings for a particular property for travel to Vancouver CBD tend to be negatively correlated with those for the same property for travel to YVR, Brighthouse, and Olympic Village, which is perhaps a sign that these latter locations may be “substitutes” for access to Vancouver CBD. But the marginal effects for travel from a given property to YVR, Brighthouse, and Olympic Village all tend to move in the same direction.

It is well established that commercial property values immediately adjacent to a rail rapid transit line can change as a result, but a major policy implication of our analysis is that properties distant from a new rail rapid transit line can see changes in value as well. Because rail rapid transit offers faster and more reliable travel times it represents a step-change in intra-metropolitan mobility so it should not be a surprise that its impacts are wide. One immediate implication is that the cost-benefit analyses of rail rapid transit investments should cast a wider net in terms of impacts on commercial property values. Another implication is that increased property tax revenue associated with increased valuations, or the ability to set a lower mill rate to generate a certain amount of tax revenue, can extend across municipal boundaries to jurisdictions that may not be contributing to the construction of the rail line.

In general, Winston and Maheshiri (2007) have found that rail transit can be very costly to construct. When there are dramatic impacts – both in terms of employment and impacts on real estate values – these costs may be justified. Our results have implications for understanding whether or not the City of Vancouver’s decision to fund and build the Olympic Village rail rapid transit station, for instance, was sound, recognizing that we have to consider the time horizon over which costs and benefits would be assessed. Relatively few commercial properties in the metro area benefit from shorter travel times to Olympic Village station.

Regardless of the net impacts, some of our results imply that expectations of enhanced access to the major business districts with the Canada Line had a substantial impact on the businesses in other parts of the metro area through the agglomeration associated with labor market pooling. But rail rapid transit has negatively impacted commercial property values in other locations, possibly due to expectations of higher taxes and diversion of public funds away from other types of infrastructure. Our nonparametric approach, which enables us to capture heterogeneity of the effects on property values, constitute a substantial contribution to the literature on rail rapid transit impacts that can also generate useful information for policy makers on how and where allocation of their scarce resources have been fruitful. In applications to other settings, our findings of variation in effects across space is generalizable to other locations; however, the specific patterns relative to the rail stations are likely to differ depending on the particular landscape of individual cities.

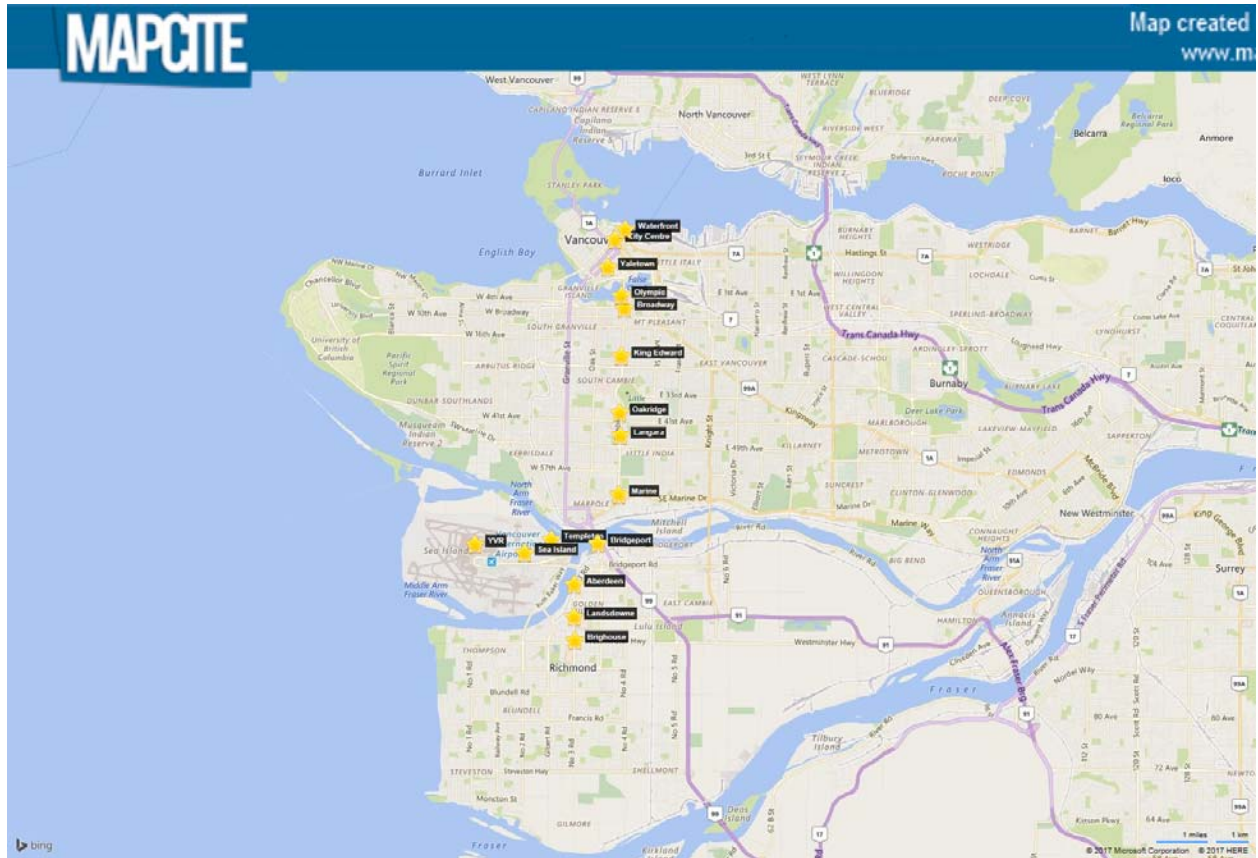
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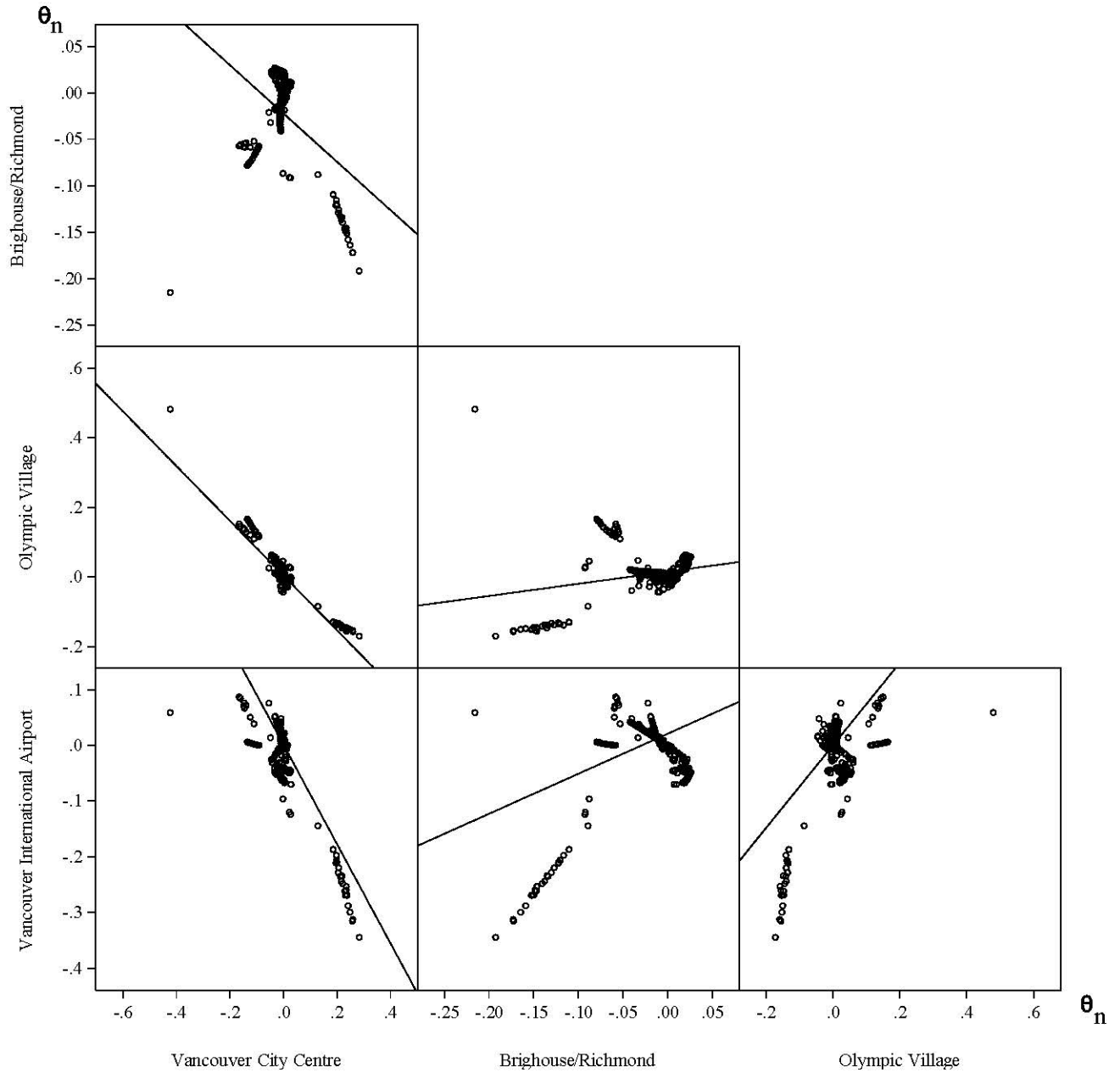
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**Figure 1: Locations of Each of the Canada Line Stations (denoted by yellow stars)**



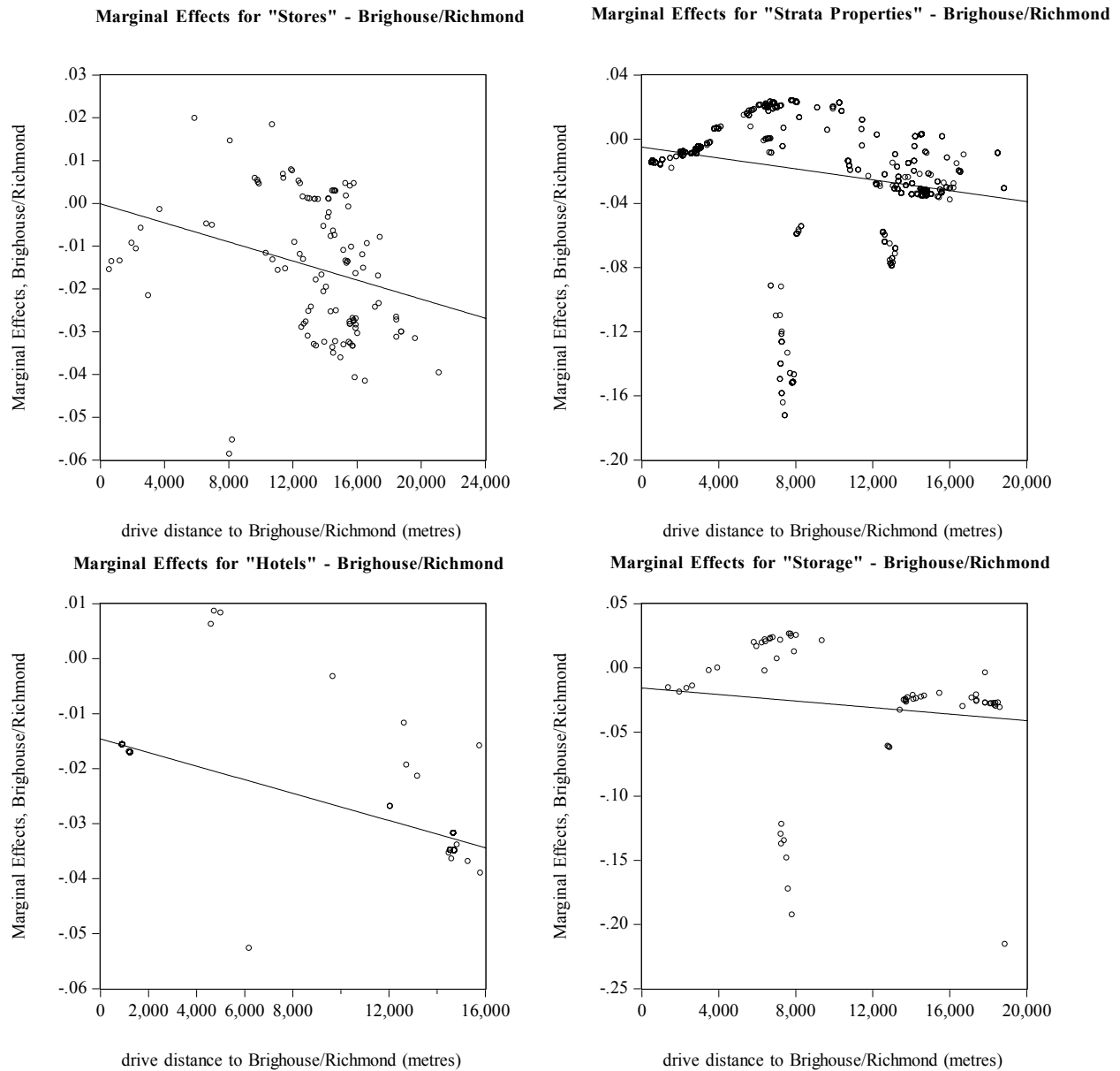
**Figure 2: Marginal Effects ( $\theta_n$ ) of Travel Time Savings on Commercial Property Values, Travel to 4 Rail Stations (Brighouse, Vancouver City Centre, Olympic Village, YVR)**



These plots are for all  $n=1,2,\dots,1895$  repeat sales properties between 1995-2016 that straddle the Canada Line announcement date of 6/24/1998.

Negative marginal effects imply that travel time savings (i.e., reductions) lead to property value increases.

**Figure 3a: Marginal Effects, Brighouse/Richmond vs. Distance; Various Land Use Types**



**Notes:**

Negative marginal effects imply that a travel time savings leads to property value increases.

BC Assessment Actual Use Type Codes:

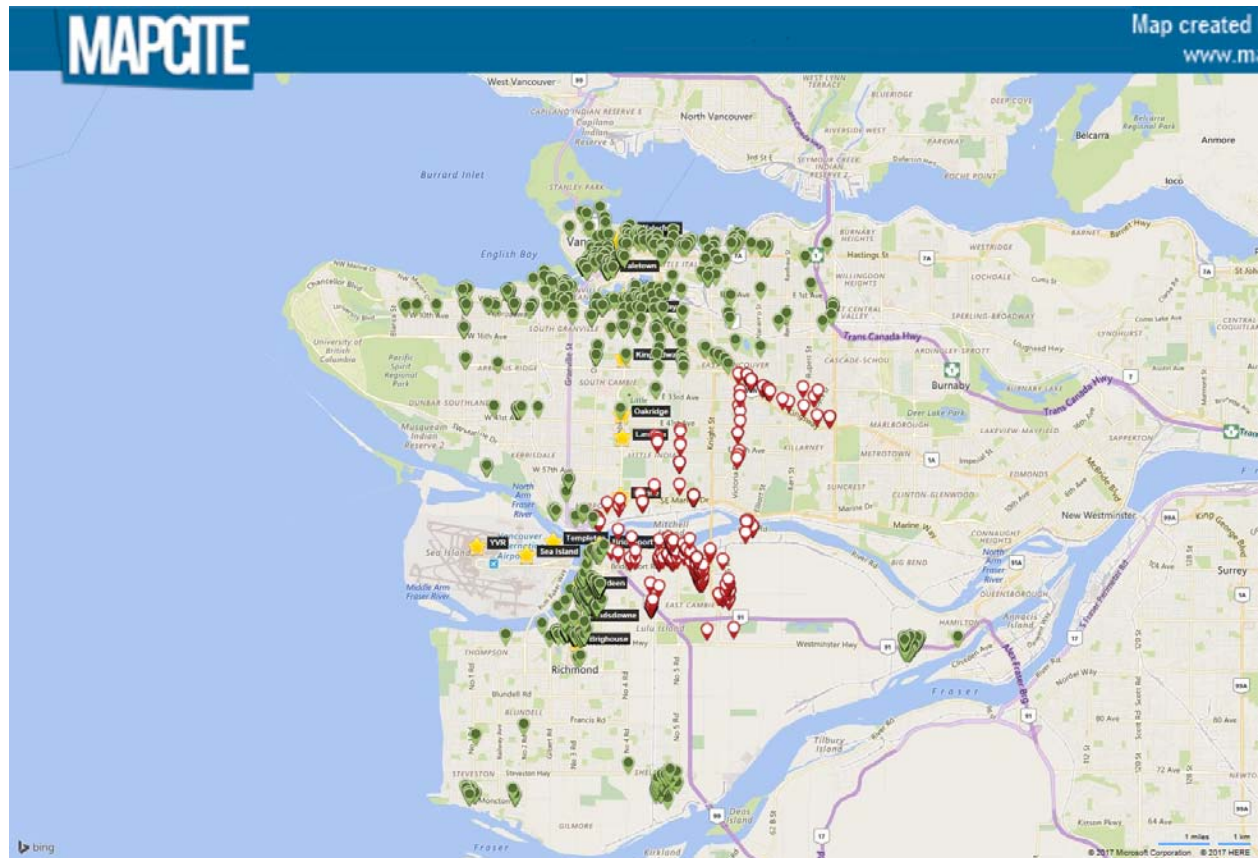
Stores: 200, 202, 204

Strata: 216 (Commercial Strata Properties)

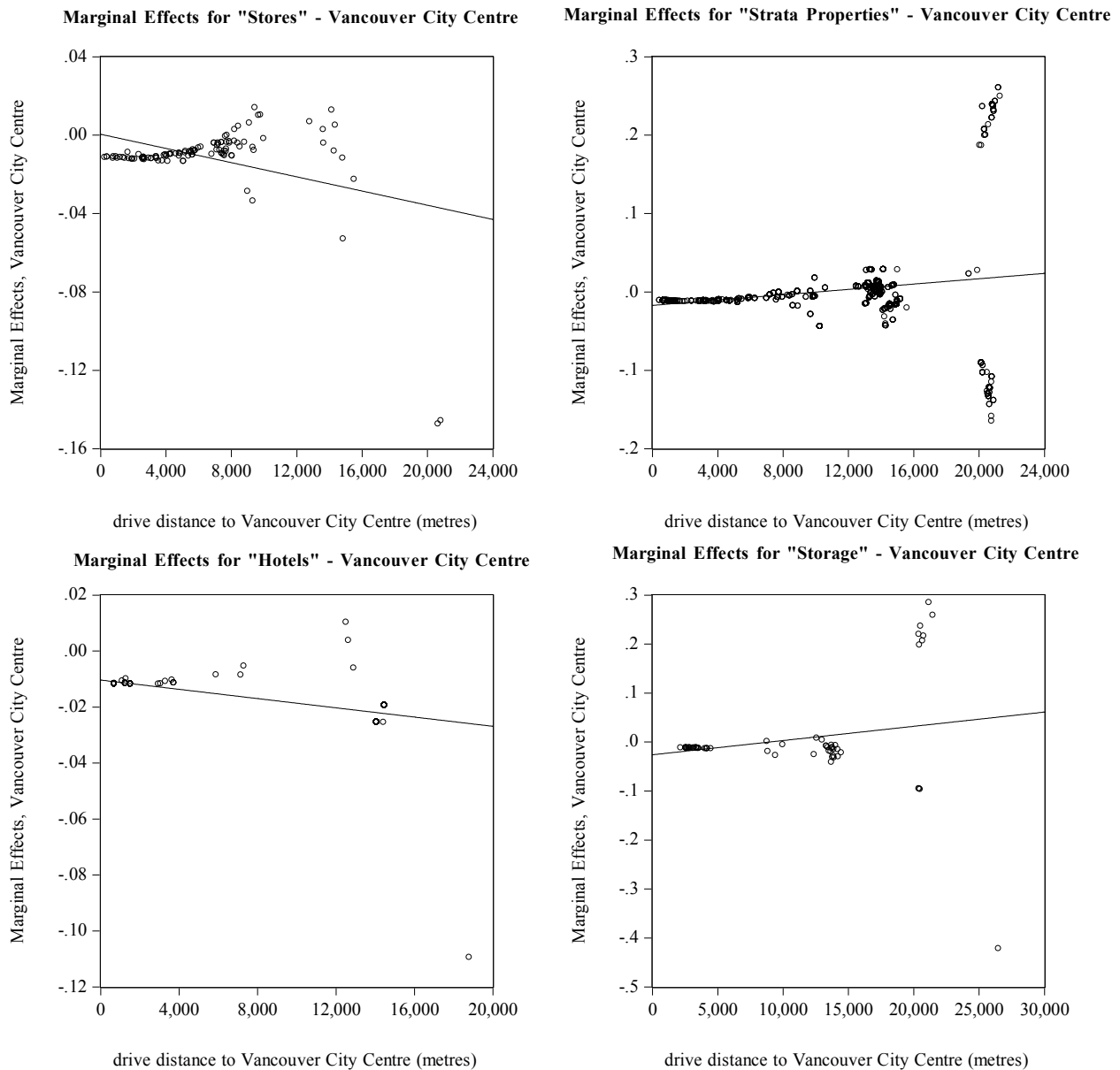
Hotels: 230, 232, 233, 237, 239

Storage: 273 (storage & warehousing, closed)

Figure 3b: Negative (green) and Positive (red) Coefficients, Brighthouse Station



**Figure 4a: Marginal Effects, Vancouver City Centre vs. Distance; Various Land Use Types**



**Notes:**

Negative marginal effects imply that a travel time savings leads to property value increases.

BC Assessment Actual Use Type Codes:

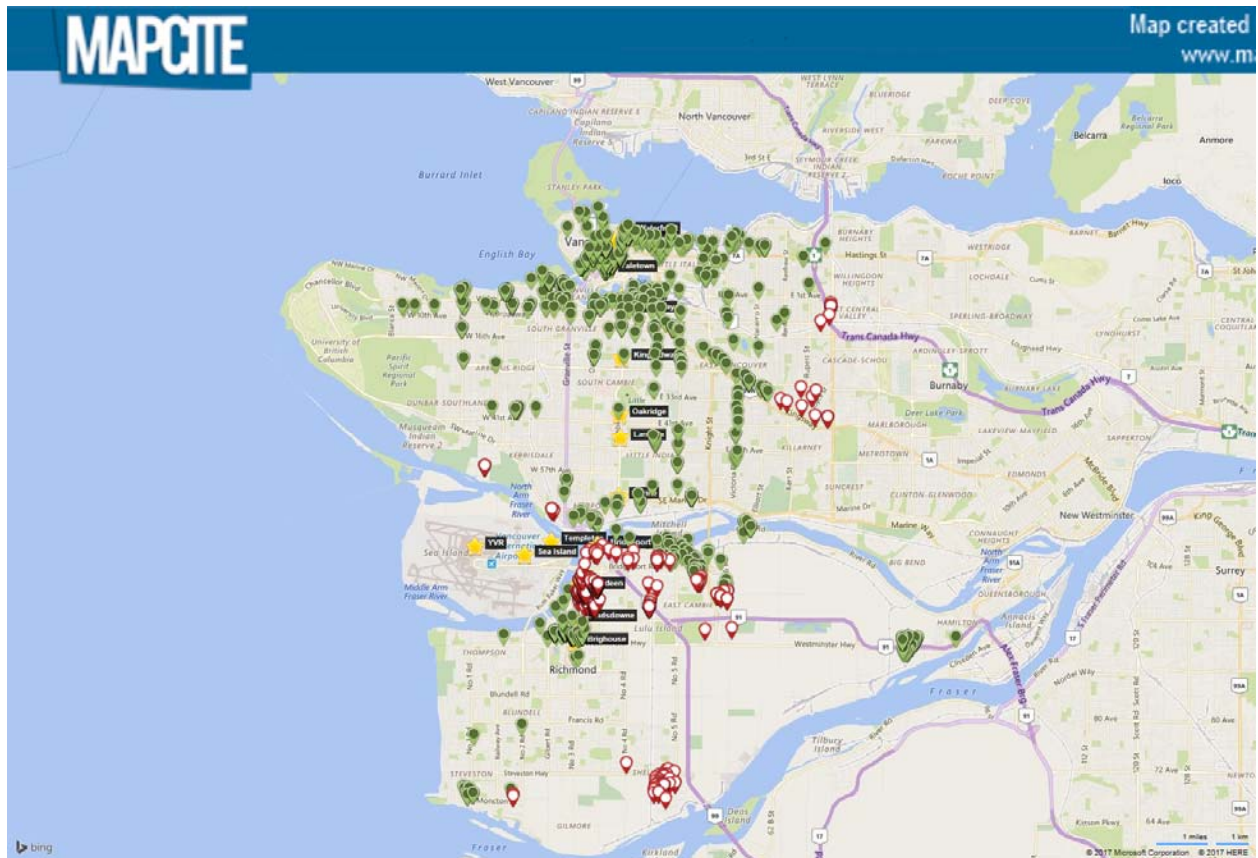
Stores: 200, 202, 204

Strata: 216 (Commercial Strata Properties)

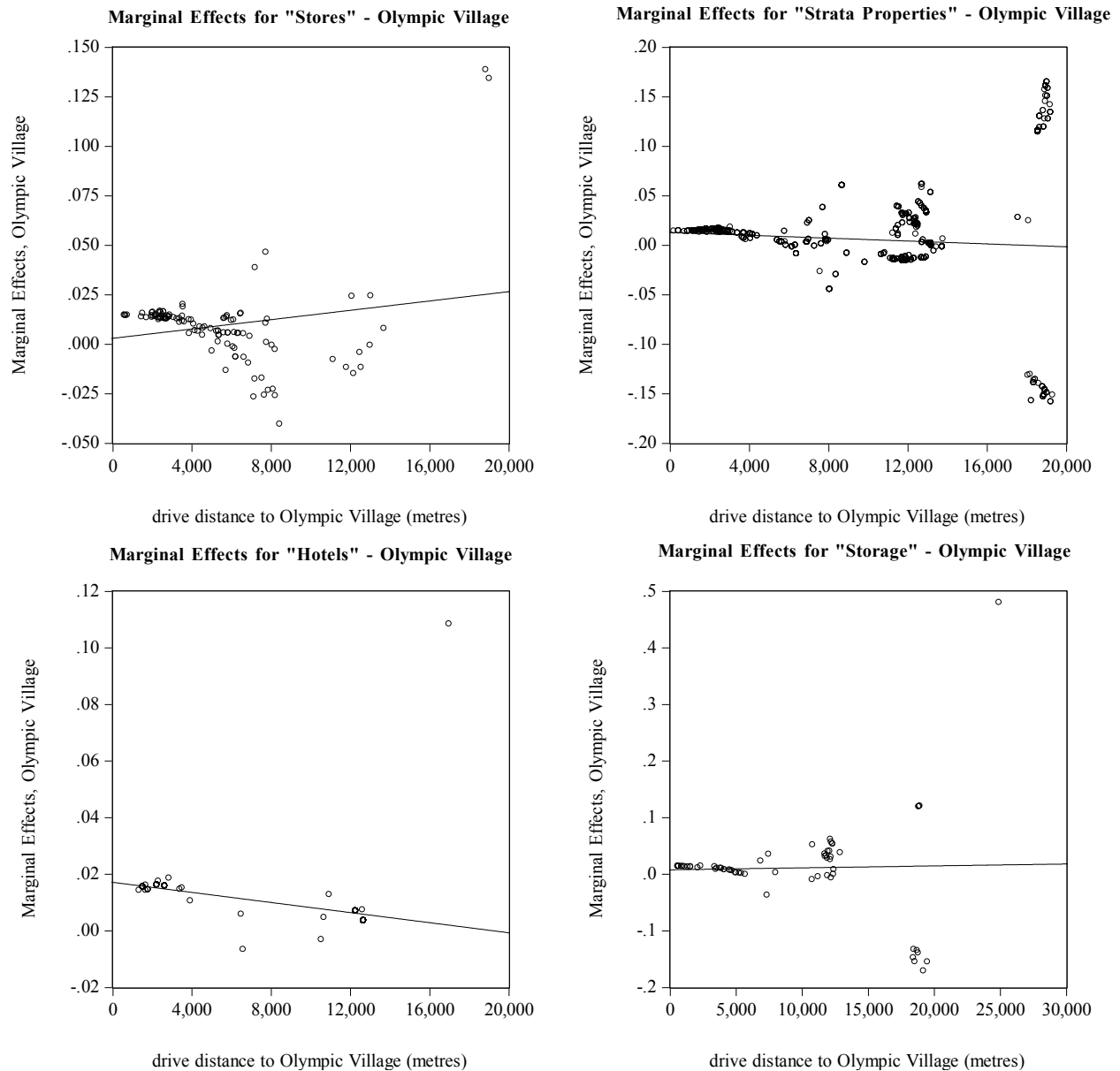
Hotels: 230, 232, 233, 237, 239

Storage: 273 (storage & warehousing, closed)

**Figure 4b: Negative (green) and Positive (red) Coefficients, Vancouver City Centre Station**



**Figure 5a: Marginal Effects, Olympic Village vs. Distance; Various Land Use Types**



**Notes:**

Negative marginal effects imply that a travel time savings leads to property value increases.

BC Assessment Actual Use Type Codes:

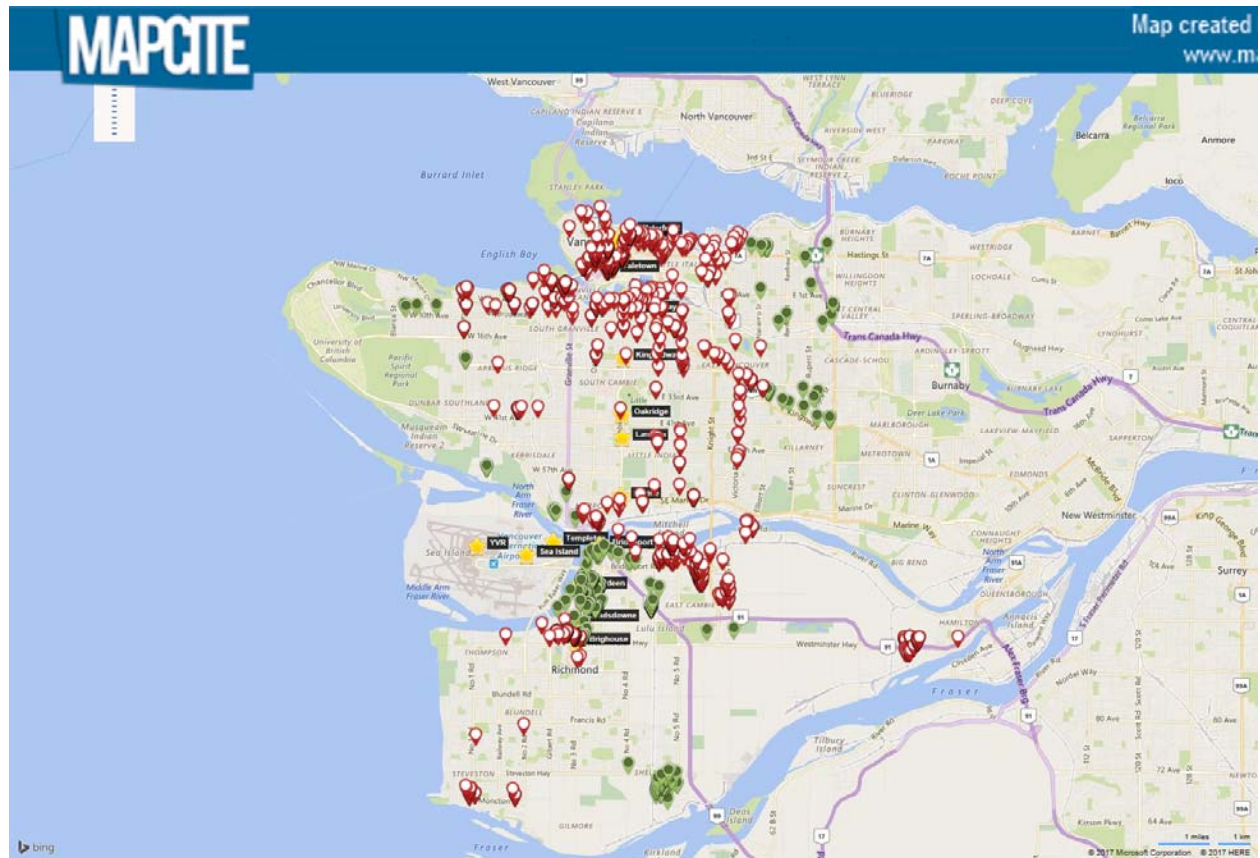
Stores: 200, 202, 204

Strata: 216 (Commercial Strata Properties)

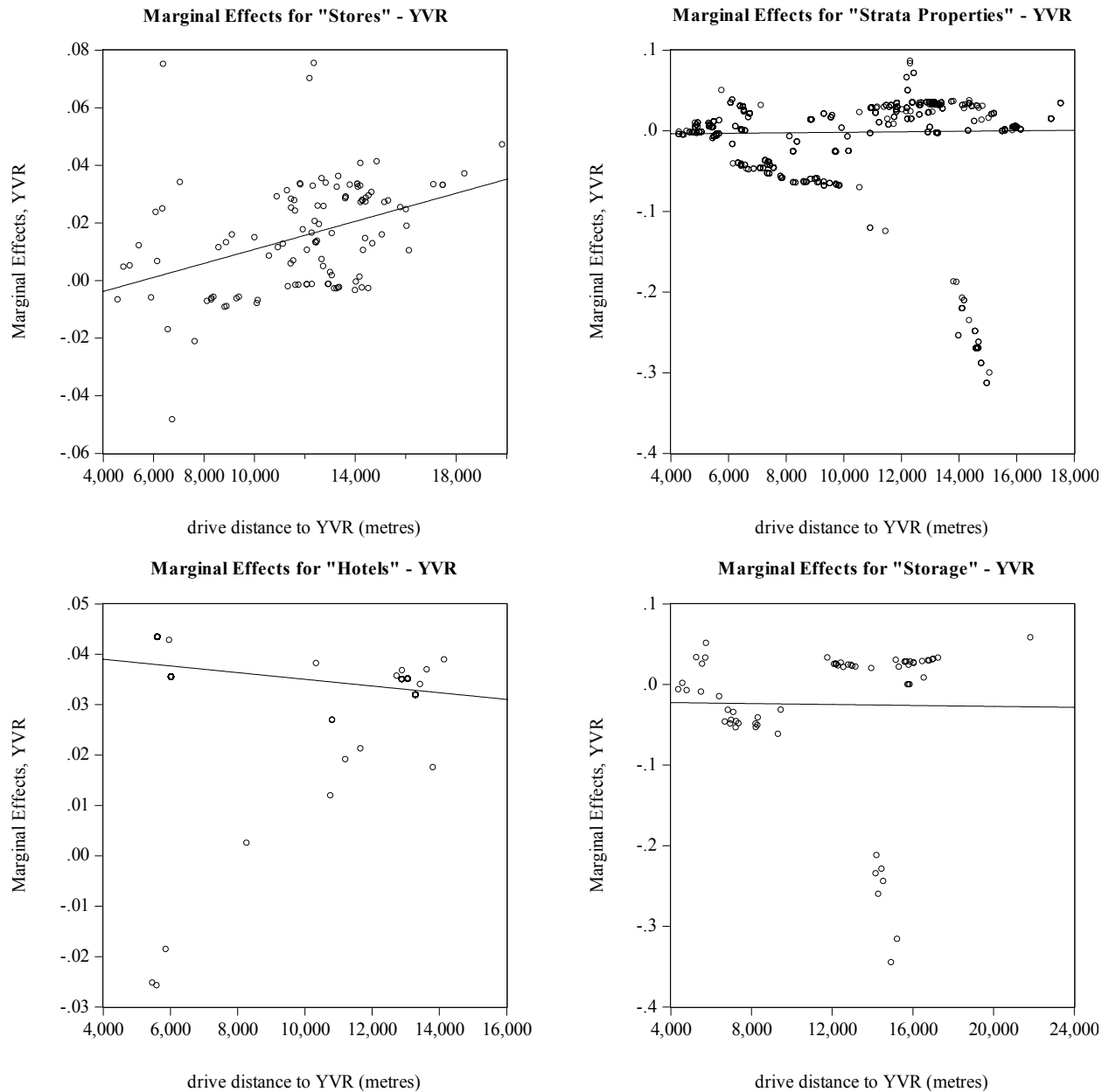
Hotels: 230, 232, 233, 237, 239

Storage: 273 (storage & warehousing, closed)

**Figure 5b: Negative (green) and Positive (red) Coefficients, Olympic Village Station**



**Figure 6a: Marginal Effects, YVR vs. Distance; Various Land Use Types**



**Notes:**

Negative marginal effects imply that a travel time savings leads to property value increases.

BC Assessment Actual Use Type Codes:

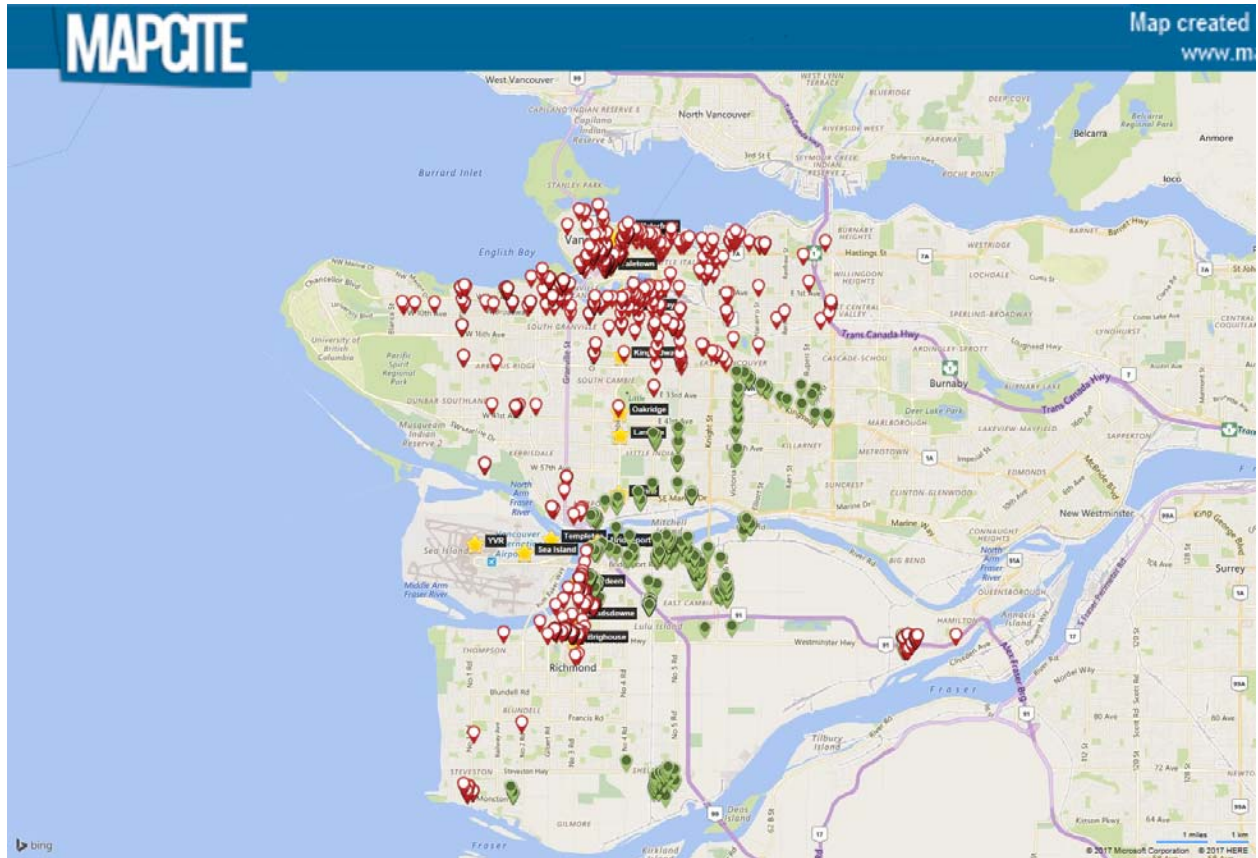
Stores: 200, 202, 204

Strata: 216 (Commercial Strata Properties)

Hotels: 230, 232, 233, 237, 239

Storage: 273 (storage & warehousing, closed)

Figure 6b: Negative (green) and Positive (red) Coefficients, YVR Station



**Table 1: Descriptive Statistics, Commercial Repeat Sales Sample in Richmond and Vancouver, BC, 1995-2016**

| <b>Variable</b>                               | <b>Units</b> | <b>Mean</b> | <b>Std. Dev</b> | <b>Maximum</b> | <b>Minimum</b> | <b>N</b> |
|-----------------------------------------------|--------------|-------------|-----------------|----------------|----------------|----------|
| Last Sale Price                               | C\$          | \$ 705,340  | \$ 2,956,150    | \$ 62,867,000  | \$ 1,000       | 1895     |
| Log of Sale Price Ratio for Repeat Sale Pairs |              | 0.076       | 0.637           | 6.415          | -7.696         | 1895     |
| Drive Time to Brighouse/Richmond              | minutes      | 29.26       | 50.88           | 179.38         | 0.73           | 1895     |
| Drive Time to Vancouver City Centre           | minutes      | 18.57       | 32.22           | 172.22         | 0.82           | 1895     |
| Drive Time to Olympic Oval                    | minutes      | 17.45       | 27.50           | 148.20         | 0.80           | 1895     |
| Drive Time to Airport                         | minutes      | 32.45       | 48.75           | 173.07         | 5.67           | 1895     |
| Time Change to Brighouse/Richmond             | minutes      | -14.66      | 46.85           | 11.10          | -150.40        | 1895     |
| Time Change to Vancouver City Centre          | minutes      | -3.33       | 29.82           | 12.70          | -146.75        | 1895     |
| Time Change to Olympic Oval                   | minutes      | -5.16       | 26.05           | 8.10           | -129.73        | 1895     |
| Time Change to Airport                        | minutes      | -13.32      | 46.45           | 14.63          | -143.08        | 1895     |
| Lot Size                                      | sq ft        | 23981.32    | 58427.92        | 534045.60      | 300.00         | 305      |
| Gross Building Area                           | sq ft        | 22892.08    | 45215.00        | 303768.00      | 1.00           | 245      |
| Effective Year Built                          | year         | 1977        | 17              | 2014           | 1908           | 250      |
| Actual Year Built                             | year         | 1964        | 27              | 2014           | 1898           | 250      |

*Note: These repeat sales are the properties with sale dates that "straddle" the Canada Line announcement (6/24/1998)*

**Table 2: Commercial Property Sales in Vancouver and Richmond BC, 1995-2016 (coefficient estimates in bold; *p-values in italics*)**

|                                                                        | <i>OLS, Differencing</i>          |
|------------------------------------------------------------------------|-----------------------------------|
| <b>Dependent Variable: Log of Price Ratio for the two repeat sales</b> |                                   |
| <b><i>Independent Variables</i></b>                                    |                                   |
| Difference in Travel Time to Brighthouse                               | <b>-0.005186</b><br><i>0.2613</i> |
| Difference in Travel Time to Vancouver City Centre                     | <b>-0.020113</b><br><i>0.0000</i> |
| Difference in Travel Time to Olympic Village                           | <b>0.020752</b><br><i>0.0000</i>  |
| Difference in Travel Time to Airport                                   | <b>0.004294</b><br><i>0.3852</i>  |
| N                                                                      | 1895                              |
| R-Squared                                                              | 0.15015                           |

**NOTES:** This OLS, Differencing specification is limited to the sample of pairs of repeat sales for which the first sale is before the announcement (on June 24, 1998) of the rail line, and the second sale is after the announcement of the rail line.

For this OLS Repeat Sales specification, each travel time is the difference between the drive time and the "new" travel time (including travel time to the rail station plus time on the train) for each repeat sales pair (there are a total of 1895 repeat sales pairs).

We also include as regressors the difference between the year fixed effects for the two years of the repeat sales.

**Table 3: Descriptive Statistics for GWR Coefficients on Travel Time Savings,  $\theta_n$  from Each Commercial Property to Brighthouse/Richmond Station**

| $\theta_n$    | Mean     | Median    | Max       | Min.     | Std. Dev. | Obs. |
|---------------|----------|-----------|-----------|----------|-----------|------|
| [-0.25, -0.2) | -0.21539 | -0.215386 | -0.215386 | -0.21539 | NA        | 1    |
| [-0.2, -0.15) | -0.15822 | -0.151977 | -0.151471 | -0.19236 | 0.010471  | 25   |
| [-0.15, -0.1) | -0.13258 | -0.129535 | -0.109905 | -0.1496  | 0.011888  | 31   |
| [-0.1, -0.05) | -0.06757 | -0.064006 | -0.052624 | -0.09202 | 0.010371  | 72   |
| [-0.05, 0)    | -0.02142 | -0.021492 | -6.60E-05 | -0.04152 | 0.011237  | 1453 |
| [0, 0.05)     | 0.013413 | 0.016112  | 0.026621  | 3.92E-05 | 0.008427  | 313  |
| All           | -0.02115 | -0.017048 | 0.026621  | -0.21539 | 0.02944   | 1895 |

$\theta_n < 0$  implies travel time savings (i.e., travel time reductions) lead to higher commercial property values

**Table 4: Descriptive Statistics for GWR Coefficients on Travel Time Savings,  $\theta_n$  from Each Commercial Property to Vancouver City Centre Station**

| $\theta_n$   | Mean     | Median    | Max       | Min.     | Std. Dev. | Obs. |
|--------------|----------|-----------|-----------|----------|-----------|------|
| [-0.5, -0.4) | -0.4215  | -0.421501 | -0.421501 | -0.4215  | NA        | 1    |
| [-0.2, -0.1) | -0.12444 | -0.128423 | -0.102495 | -0.16455 | 0.015269  | 50   |
| [-0.1, 0)    | -0.01415 | -0.011694 | -1.76E-05 | -0.09621 | 0.011151  | 1363 |
| [0, 0.1)     | 0.011081 | 0.011078  | 0.030648  | 7.81E-05 | 0.007143  | 424  |
| [0.1, 0.2)   | 0.183545 | 0.19287   | 0.199776  | 0.130286 | 0.026734  | 6    |
| [0.2, 0.3)   | 0.231338 | 0.236808  | 0.284864  | 0.200263 | 0.017987  | 51   |
| All          | -0.0044  | -0.011277 | 0.284864  | -0.4215  | 0.048165  | 1895 |

$\theta_n < 0$  implies travel time savings (i.e., travel time reductions) lead to higher commercial property values

**Table 5: Descriptive Statistics for GWR Coefficients on Travel Time Savings,  $\theta_n$  from Each Commercial Property to Olympic Village Station**

| $\theta_n$   | Mean     | Median    | Max       | Min.     | Std. Dev. | Obs. |
|--------------|----------|-----------|-----------|----------|-----------|------|
| [-0.2, -0.1) | -0.14643 | -0.147882 | -0.130272 | -0.17056 | 0.008198  | 56   |
| [-0.1, 0)    | -0.01416 | -0.01457  | -0.00029  | -0.08511 | 0.008861  | 452  |
| [0, 0.1)     | 0.014913 | 0.015391  | 0.061965  | 8.89E-05 | 0.010681  | 1319 |
| [0.1, 0.2)   | 0.136555 | 0.1344    | 0.165161  | 0.10854  | 0.01812   | 67   |
| [0.4, 0.5)   | 0.48062  | 0.48062   | 0.48062   | 0.48062  | NA        | 1    |
| All          | 0.007758 | 0.012661  | 0.48062   | -0.17056 | 0.04086   | 1895 |

$\theta_n < 0$  implies travel time savings (i.e., travel time reductions) lead to higher commercial property values

**Table 6: Descriptive Statistics for GWR Coefficients on Travel Time Savings,  $\theta_n$  from Each Commercial Property to Vancouver International Airport (YVR) Station**

| $\theta_n$    | Mean     | Median    | Max       | Min.     | Std. Dev. | Obs. |
|---------------|----------|-----------|-----------|----------|-----------|------|
| [-0.35, -0.3) | -0.31986 | -0.312836 | -0.312836 | -0.34495 | 0.014088  | 5    |
| [-0.3, -0.25) | -0.2714  | -0.269779 | -0.253943 | -0.2999  | 0.010357  | 28   |
| [-0.25, -0.2) | -0.22693 | -0.220212 | -0.207105 | -0.24863 | 0.014201  | 20   |
| [-0.2, -0.15) | -0.19091 | -0.187587 | -0.187118 | -0.19802 | 0.006163  | 3    |
| [-0.15, -0.1) | -0.12765 | -0.12256  | -0.120535 | -0.14496 | 0.011695  | 4    |
| [-0.1, -0.05) | -0.06163 | -0.060054 | -0.050498 | -0.09663 | 0.006423  | 77   |
| [-0.05, 0)    | -0.01543 | -0.007061 | -9.67E-06 | -0.04895 | 0.016411  | 447  |
| [0, 0.05)     | 0.027643 | 0.03195   | 0.049852  | 7.89E-06 | 0.011104  | 1298 |
| [0.05, 0.1)   | 0.068994 | 0.071505  | 0.086356  | 0.0502   | 0.010851  | 13   |
| All           | 0.005443 | 0.025819  | 0.086356  | -0.34495 | 0.053729  | 1895 |

$\theta_n < 0$  implies travel time savings (i.e., travel time reductions) lead to higher commercial property values

**Table 7: Estimated Trip Generation Rates, Average Weekday Vehicle Trips/1000 sf GLA**

| <b>Land Use:</b>             | <b>Retail<br/>Stores</b> | <b>Storage<br/>Facilities</b>         | <b>Hotels</b> | <b>Strata Properties</b>                                                |
|------------------------------|--------------------------|---------------------------------------|---------------|-------------------------------------------------------------------------|
| <i>Trip Generation Rate:</i> | <i>Very low*</i>         | 2.5 (Self-Storage)<br>3.6 (Warehouse) | 20.5**        | 7.0 (General Light<br>Industrial/Industrial Park)<br>11.4 (Office Park) |

Source: Institute of Transportation Engineers (ITE), *Trip Generation*, 8<sup>th</sup> Edition, 2008

\*ITE do not have trip generation rates for neighbourhood “Mom and Pop” convenience stores and restaurants, but since access to these establishments is mainly by foot, the vehicle trip generation rate is probably very low.

\*\*Based on ITE rate of 8.9 trips per occupied room, an average room size of 325 sf and hotel occupancy rate of 75%.

**Table 8: Commercial Property Sales in Coquitlam and Port Coquitlam, BC, 1975-1994**  
**Falsification Test Results** (coefficient estimates in bold; *p-values in italics*)

|                                                               |  | <i>Model Specification:</i><br><i>OLS, Differencing</i> |
|---------------------------------------------------------------|--|---------------------------------------------------------|
| <b>Dependent Variable:</b>                                    |  |                                                         |
| <i>Log of Price Ratio, Including Repeat Sales Price Index</i> |  | <b>YES</b>                                              |
| <b>Repeat Sales Sample</b>                                    |  | <b>YES</b>                                              |
| <br><i>Independent Variables:</i>                             |  |                                                         |
| Travel Time to Brighthouse                                    |  | <b>1.29E-01</b><br><i>0.341</i>                         |
| Travel Time to Vancouver City Centre                          |  | <b>-5.62E-03</b><br><i>0.887</i>                        |
| Travel Time to Olympic Village                                |  | <b>2.89E-02</b><br><i>0.23</i>                          |
| Travel Time to Airport                                        |  | <b>-0.124</b><br><i>0.418</i>                           |
| GWR bandwidth test                                            |  | <b>8040</b>                                             |
| (When P-Value>0.05, GWR does no better than OLS)              |  | <i>1.000</i>                                            |
| N                                                             |  | 293                                                     |
| R-Squared                                                     |  | 0.2827                                                  |

**NOTES:** The OLS, Differencing specification is limited to the sample of pairs of repeat sales for which the first and last sales are before January 1, 1995, for the Cities of Coquitlam and Port Coquitlam (which are located in British Columbia but relatively "far" from Vancouver and Richmond)

For the OLS Repeat Sales specification, each travel time is the difference between the drive time and the "new" travel time (including travel time to the rail station plus time on the train) for each repeat sales pair (there are 293 repeat sales pairs in Coquitlam and Port Coquitlam).

The GWR bandwidth test is highly insignificant, implying that there is no significant improvement with GWR over OLS in this falsification model.

**Table 9: Balancing Tests Results**

**Dependent Variable:** Travel Time Savings, Commercial Properties to Brighthouse/Richmond Station  
**Estimation Method:** OLS, including repeat sales price indexes as independent variables (estimates not shown)

| <b>Independent Variables:</b>    | <b>Estimate</b> | <b>P-Value</b> | <b>N</b> | <b>R-squared</b> |
|----------------------------------|-----------------|----------------|----------|------------------|
| $\text{Log}(P_{n,t+j} / P_{nt})$ | -1.31485        | 0.4999         | 1895     | 0.077286         |

**Dependent Variable:** Travel Time Savings, Commercial Properties to Vancouver City Centre Station  
**Estimation Method:** OLS, including repeat sales price indexes as independent variables (estimates not shown)

| <b>Independent Variables:</b>    | <b>Estimate</b> | <b>P-Value</b> | <b>N</b> | <b>R-squared</b> |
|----------------------------------|-----------------|----------------|----------|------------------|
| $\text{Log}(P_{n,t+j} / P_{nt})$ | -1.93946        | 0.1202         | 1895     | 0.066137         |

**Dependent Variable:** Travel Time Savings, Commercial Properties to Olympic Village Station  
**Estimation Method:** OLS, including repeat sales price indexes as independent variables (estimates not shown)

| <b>Independent Variables:</b>    | <b>Estimate</b> | <b>P-Value</b> | <b>N</b> | <b>R-squared</b> |
|----------------------------------|-----------------|----------------|----------|------------------|
| $\text{Log}(P_{n,t+j} / P_{nt})$ | -0.97781        | 0.3706         | 1895     | 0.063053         |

**Dependent Variable:** Travel Time Savings, Commercial Properties to Vancouver International Airport Station  
**Estimation Method:** OLS, including repeat sales price indexes as independent variables (estimates not shown)

| <b>Independent Variables:</b>    | <b>Estimate</b> | <b>P-Value</b> | <b>N</b> | <b>R-squared</b> |
|----------------------------------|-----------------|----------------|----------|------------------|
| $\text{Log}(P_{n,t+j} / P_{nt})$ | -1.72939        | 0.3749         | 1895     | 0.061528         |

Notes: With these "Balancing Tests", as in Bifulco et al (2011), we test for reverse causality. The insignificant parameter estimates (with P-Value>0.05 throughout) on the sale price ratio term imply there is no significant reverse causality in our model.