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

Jeffrey P. Cohen (corresponding author)
University of Connecticut
Jeffrey.Cohen@uconn.edu

Mike Brown
Greater Toronto Airports Authority

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 new rail rapid transit line announcement in Vancouver, BC, Canada, we identify the net capitalization effect for individual commercial property prices resulting from improved urban center access. We focus on 1,895 repeat sales straddling the 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; property values

JEL Codes: R3, R4

November 11, 2016

We benefitted from comments on earlier versions of this paper from seminar participants at University of British Columbia, Rutgers University, Georgia Tech, and the Vancouver Airport Authority; the 2014 German Aviation Research Society workshop in Amsterdam; and a session at the 2014 Allied Social Sciences Association meetings in Philadelphia. Steve Ross, John Clapp, Anming Zhang, Jason Barr, Pat McCarthy, Peter Loeb, and Resul Cesur also provided helpful comments. Any remaining errors are our own.

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

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 new rail rapid transit line announcement in Vancouver, BC, Canada, we identify the net capitalization effect for individual commercial property prices resulting from improved urban center access. We focus on 1,895 repeat sales straddling the 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; property values

JEL Codes: R3, R4

November 11, 2016

We benefitted from comments on earlier versions of this paper from seminar participants at University of British Columbia, Rutgers University, Georgia Tech, and the Vancouver Airport Authority; the 2014 German Aviation Research Society workshop in Amsterdam; and a session at the 2014 Allied Social Sciences Association meetings in Philadelphia. Steve Ross, John Clapp, Anming Zhang, Jason Barr, Pat McCarthy, Peter Loeb, and Resul Cesur also provided helpful comments. Any remaining errors are our own.

Introduction

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 and resource diversion away from other infrastructure. Thus, 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 identify the net capitalization effect for individual commercial property prices resulting from improved urban center access, and we allow for the possibility that the net effect can be beneficial to some commercial properties and detrimental to 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).[1] For instance, access to workers is crucial for businesses that provide the many service jobs at or around the airport (Brueckner, 2003). Also, many city centres are hubs for economic activity. Ease of access to these employment opportunities can encourage the most productive workers to agglomerate and live in neighborhoods where their commute times would be low (Fu and Ross, 2013), which can help sustain businesses close by that these individuals may patronize. Also, these "agglomeration economies" (Duranton and Puga, 2004; Puga, 2010) can enable people who live in or near the urban centres to more easily reach other businesses throughout the urban areas with the advent of faster and more reliable travel. Assuming people prefer to minimize their travel

[1] Another reason that commercial property values may be positively affected by rail rapid transit is that it allows property owners to devote less space to vehicle parking and possibly convert surplus parking supply to uses that generates more revenue or add to the amenity value of the property (for example, replacing surface parking stalls with a small park).

costs for non-employment related business transactions (such as shopping, services, etc.), they may be also expected to shop close to their commuting route. This beneficial business transactions volume can become another source of capitalization into commercial property values if workers cluster in neighborhoods with improved transportation access to employment opportunities, and/or near new transit stations. Similarly, clusters of workers in various neighborhoods throughout a city can lead to agglomeration economies for firms due to labor market pooling, which can make access to those locations outside of the business centres more valuable for businesses. At the same time, greater congestion due to higher consumer traffic associated with growth, and/or the disruption of businesses due to construction of transit infrastructure, may have negative effects on commercial property values following an "announcement" of new transit service. 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 is the effect of a new rail rapid transit line on commercial property values? And, is the answer to this question different at various locations throughout a city?

There have been several recent studies on the impacts of airport and central business district access upon residential housing and land and/or property values, but there has been relatively little known research on the impact of access on commercial property values incorporating the announcement of rail rapid transit as an identification strategy.[2] Recent research on the concept of airport cities, for example, provides some supporting evidence in both

[2] 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.

directions. Specifically, Appold (2015) finds evidence in favor of an aerotropolis argument across 51 U.S. metropolitan areas. Appold and Kasarda (2013) find evidence of the growing stature of airports as central business districts in several U.S. cities. On the other hand, Cidell (2015) finds that arguments for an airport city in the U.S. tend to over-state the potential impacts of an airport. Also, Diao et al (2015) note that job growth associated with public infrastructure (such as rail and airports) can also lead to congestion on access roads, which may detrimentally impact businesses and make their property locations less desirable.

In this 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).

On June 24, 1998, there was a "surprise announcement" that the Canada Line (an elevated rail rapid transit line) would be built,[3] connecting the Richmond CBD with YVR, the 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 truck 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. The goal was to move quickly with construction, in part in order to help lure the 2010 Olympics to the city. Also, as a central gateway to Asia and the remainder of North America, access to YVR for workers and for some business travelers is crucial. Our goal is to determine how commercial property values are affected by changes in

[3] "SkyTrain Line to Airport Proposed", *Vancouver Sun*, June 25, 1998.

travel time between these four business centres and commercial properties throughout Richmond and Vancouver.

A priori, the direction of the effect of changes in 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.

We estimate a nonparametric empirical model, which allows for the possibility of heterogeneity in the sign and magnitudes of these impacts on commercial property values, using the announcement of a new rail rapid transit line as part of our identification strategy. 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).[4] We estimate the model using Locally Weighted Regressions[5] (LWR) and we find that shorter travel time between commercial properties in the Cities of Vancouver and Richmond and each of the 4 urban centres as a result of the Canada Line

[4] 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.

[5] McMillen and Redfearn (2010) indicate that Locally Weighted Regressions (LWR) is equivalent to Geographically Weighted Regressions (GWR). Therefore, in this paper we use the two terms interchangeably.

announcement led to increases in the sale prices of some commercial properties and decreases in sale prices of other commercial properties. Our falsification and balancing tests validate our findings. Our focus on the relatively under-studied commercial property impacts, along with the nonparametric approach that allows for marginal effects which can vary across locations, are some of the major contributions of our analysis that we present in more detail below.

The remainder of this paper is organized as follows. First, we review the literature on the property value impacts of proximity to rail rapid transit and to airports, and provide some background on Metro Vancouver. Then we describe the details of our specific problem and of our empirical modeling approach. Next we provide a brief explanation of the data, followed by an exposition and interpretation of the results. Finally, we discuss the conclusions and some policy implications of these results.

Literature Review and Background on Metro Vancouver, BC

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).[6] There were 1.36 million people employed in the metro area in June 2016, with an unemployment rate of 5.4%.[7] The Vancouver CBD is the major employment center of the metropolitan area. In 2012, Vancouver Interntational Airport (YVR) – which is located in Richmond, BC - served 17.6 million enplaned-deplaned passengers of which

[6] 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.
[7] http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/lfss03l-eng.htm ; accessed July 26, 2016.

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.[8] 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 (five years after the Canada Line announcement), Vancouver was officially awarded the 2010 Olympic Winter Games, in part due to its strong security plans, sports and other facilities and "Athletes' Village".[9] 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.[10] With the Canada Line opening in late-2009, it was up and running before the Olympics, with a station at Olympic Village.[11] Part of the intention of including a Canada Line

[8] 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.

[9] 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.

[10] http://www.huffingtonpost.ca/2011/10/27/vancouver-olympics-economic-benefit_n_1035427.html ; accessed July 26, 2016.

[11] 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.

station at the Olympic Village was to accommodate some commercial demand that could not be met in the Vancouver CBD.[12]

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.

In more general settings, there are many studies examining the impacts of transportation infrastructure on property values, some of which compare the tradeoffs between enhanced residential property values and greater noise associated with airport and/or other transportation infrastructure improvements.[13] Others, such as Duranton and Turner (2011), Anderson (2014), and Bauernschuster et al (forthcoming), focus on the relationship between transit and road usage or congestion. Few known previous studies, however, focus on the nexus of commercial property impacts[14,15] from proximity to specific business centers in two cities and an airport in the region, using the announcement of a rail rapid transit as an identification strategy.

Much of the early work in this area focuses on hedonic housing price models, and to a much smaller extent, commercial property impacts of airports and/or transit proximity. There is also a strand of literature with a focus on transit's impact on property values. The focus of Baum-

[12] City of Vancouver 2009 Metro Core Jobs and Economy Land Use Plan.
[13] For instance, Tomkins et al (1998) find the benefits of residential location near airports exceed the costs.
[14] The lack of research on commercial property value impacts of airports was pointed out to us by Jan Brueckner.
[15] 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.

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 rigorous 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. Their study finds 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 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.

In the airports proximity literature, Crowley (1973) studies the effect of airports on land values in an area next to Toronto International Airport (Malton). The analysis looks at residential, commercial, industrial and public land prices for both sales and rent in the years 1955 – 1969. Specifically, the study compares the land value changes of the properties near the airport relative to land prices farther away and evaluates the changes in the mix of land uses (industrial vs. commercial vs. residential). The study concludes that residential land values decreased during "shock years" when there were substantial changes but typically rebounded to their initial levels soon thereafter. The author hypothesizes that this initial decrease in price may be caused by a significant population putting their houses up for sale to prematurely to avoid potential noise related issues in the future.

A more recent study of the commercial property impacts of airports is Cohen and Morrison Paul (2007).[16] They assess the impacts on manufacturing property values of airport infrastructure stocks aggregated to the U.S. state-level. They find airport infrastructure improvements in a particular state enhance the commercial property values for the manufacturing sector in that state. A shortcoming of their approach, however, is the level of aggregation of the data at the state level, as well as potential endogeneity of the infrastructure variables.

[16] Much of the early literature on the impacts of public infrastructure – such as Aschauer (1989) and Kelejian and Robinson (1997) – focused exclusively on the effects of spending (and/or public infrastructure capital) on productivity or costs. But Cohen and Morrison Paul (2007) was one of the first known studies that built property values into an empirical model that can assess both the productivity/costs effect and the property value effect.

Cohen and Coughlin (2008) study the relationship between distance to the Atlanta airport and housing prices in the surrounding areas. They find that for every ten percent increase in distance to the airport, housing sale prices fall by an average of 1.5 percent, after controlling for several other factors that might affect sale price. Other recent studies of the impacts of airport proximity on housing prices include McMillen (2004), and Tompkins et al (1998).[17]

For our empirical analysis, one goal is to determine how expected (and/or actual) changes in travel time to/from various urban centres, due to the rail rapid transit line announcement, are capitalized into commercial property values. Clearly there are many studies on the residential property values impacts, while relatively few known studies have explored the relationship between proximity to business centres and commercial property values, using a rail rapid transit announcement as an identification strategy. There is also some evidence that the direction of the impacts of transit on property values may be non-linear, based on the findings of various studies in the previous literature. In the next section 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.

Estimation Strategy

Our 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. First, we identify 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

[17] The former study focuses on Chicago home prices, while the latter examines Manchester, England. Both of these studies find that proximity to the airports tends to increase the price of housing.

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).

We motivate our analysis with an empirical model that is analogous to a hedonic housing model, except our problem is for commercial properties so it is somewhat different. Specifically, consider a model in the form:

$$\text{Log}(P_{nt}) = \mathbf{C_{n,t}}\theta + \mathbf{X_n}\phi + \varepsilon_{nt} \quad , n=1, 2,\ldots, 1895; \; t=1995, 1996,\ldots,2016. \qquad (1)$$

where $\varepsilon_{nt} = \tau_t + \upsilon_{nt}$, $\upsilon_{nt} \sim$ 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 θ) is a N by 4 matrix of the travel time from commercial property n to various landmarks at time t; τ_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 ϕ , 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). $\mathbf{X_n}$ 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.[18] 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 Brighouse 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 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:

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

where $\upsilon_{nt} \sim$ iid$(0, \sigma^2\mathbf{I})$, and $\mathbf{(C_{n,t+j} - C_{n,t})}$ 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 $\mathbf{(C_{n,t+j} - C_{n,t})}$ 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

[18] 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.

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 at these landmarks that encourages residents to live near and patronize businesses close to the 16 Canada Line stops, which in turn creates potential agglomeration economies in 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 θ 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:

$$w_{nk}\text{Log}(P_{nt}) = w_{nk}(\mathbf{C_{n,t}})\boldsymbol{\theta_n} + w_{nk}\mathbf{X_n}\boldsymbol{\phi_n} + w_{nk}(\tau_t)\,\boldsymbol{\gamma_n} + \upsilon_{nt} \qquad (3')$$

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:

$$w_{nk}\text{Log}(P_{n,t+j}/P_{nt}) = w_{nk}(\mathbf{C_{ni,t+j}} - \mathbf{C_{n,t}})\boldsymbol{\theta_n} + w_{nk}(\tau_{t+j} - \tau_t)\,\boldsymbol{\gamma_n} + \upsilon_{n,t+j} - \upsilon_{nt} \qquad (5)$$

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 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.

In the results section below, the varying signs and magnitude of the LWR marginal effects estimates $\boldsymbol{\theta_n}$ demonstrate that there are nonlinearlities in the f(•) 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; [19] actual "year 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 (Brighouse 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

[19] 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 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.

follows.[20] 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, and may commute to one of the 4 landmarks for employment opportunities. We also allow for the possibility that people who reside very close to one of the 4 landmarks choose to take the Canada Line to a commercial property somewhere in Vancouver or Richmond to conduct business, engage in a transaction, or go to work elsewhere in the metro area, etc. 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 taxi or uber) to the nearest station.[21] Once at the nearest station, individuals can take the Canada Line from that station to one of the 4 "landmark" stations: Vancouver International Airport, Olympic Village, Vancouver CBD, and Brighouse-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

[20] 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 Brighouse/Richmond) are obtained from Translink; see http://www.translink.ca/-/media/Documents/schedules_and_maps/travel_times/skytrain_schedule_between_stops_canada_line.pdf (accessed July 6, 2016).

[21] 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.

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 Brighouse 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.[22] 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.[23]

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, 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 (θ) 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 θ is positive, and the magnitude implies a one minute increase in expected

[22] 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.

[23] 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".

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. It may also be the nascent nature of Olympic Village as a business activity centre and that a certain critical mass has to be reached before commercial property values elsewhere in the city increase due to time savings created by the Canada Line. The parameter estimates on travel time savings to YVR and travel time savings to Brighouse are statistically insignificant. In the case of YVR this may because the daily volume of trips between a given property and the airport is 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. [24]

We first present the range of parameter estimates (θ_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 – Brighouse (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 of rail service. For the Brighouse 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 Brighouse section of Richmond due to the expectation and/or presence of new rail

[24] If the true relationship had been linear, we would find all θ_n coefficients equal to each other in the LWR specification. With the spatial nonstationarity test, we strongly reject the hypothesis that all θ_n , n=1,2,…,1895, are equal to each other for each travel time savings variable.

rapid transit service led to higher property values. The magnitudes of the negative estimates of θ_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 travel time savings). The range of negative values of θ_n was between -0.42 and 0. The majority of the positive values of θ_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, likely 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 travel time savings to the Olympic Village, with nearly 74% of the 1,895 properties' θ_n coefficients positive in Vancouver and Richmond. The vast majority of the positive θ_n coefficients were small (between 0 and 0.06).

Somewhat surprisingly, the overall situation is more mixed for travel time savings to YVR, with approximately 69% positive θ_n coefficients among the 1,895 commercial properties in Vancouver and Richmond. But the negative θ_n coefficients (with a minimum of -0.35) are substantially larger in absolute value than the positive θ_n coefficients (maximum of 0.08), implying that there are some properties that benefit dramatically from improved access to YVR,

possibly because the specific occupants of these properties have a higher than average propensity for air travel and therefore generate more substantial volumes of travel between the airport and the property while the magnitude of the impacts are small for those commercial properties that are detrimentally affected.

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 (θ_n) in Figure 2. It can be seen that there is a negative relationship between the θ_n for Vancouver City Centre and each of the other locations' θ_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 θ_n for these same properties for travel to YVR, Brighouse, and the Olympic Village decrease. Perhaps this implies that properties in Vancouver and Richmond benefit by access to the CBD, but these benefits come at the "expense" of the benefits of access to the other landmark locations. Possibly there was 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. In contrast, the θ_n for travel time savings to YVR, the Olympic Village, and Brighouse 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 (Brighouse, 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 (θ_n). These plots are for each of the four most common "actual land use" categories for which we have data: retail stores[25], storage facilities, hotel properties and strata properties[26]. 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 present these relationships in Figure 3 for Brighouse. 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 Brighouse station with the Canada Line announcement. While the vast majority of "stores" properties are located between 10 and 20 kilometres from Brighouse, most of these marginal effects are also negative, implying faster and more reliable access to Brighouse 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 (θ_n) as distance to Brighouse increases. For commercial "strata" properties, there are many approximately 8 kilometres from Brighouse 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.

[25] 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.
[26] "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.

For Vancouver City Centre, Figure 4 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 Brighouse). These hotel properties benefit substantially from easier access to the CBD. Also, the majority of stores have negative marginal effects (θ_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 CBD tend to benefit substantially from faster and more reliable access to/from CBD.

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 faster access to the Olympic Village. This may have been due in part to the construction disruption effects, 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. Another factor may be that the residential redevelopment of the Olympic Village neighbourhood stimulated by the Canada Line rendered the in-situ retail stores to be a poor fit with the tastes of the new residents, depressing their property values. But in Figure 5, 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 other words, anticipation of faster access from hotels to the Olympic Village raised these hotels' property values – perhaps due to the fact that spectators who stay in hotels locate further away and get to the Olympic Village relatively quickly on the Canada Line. 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 5. Once again, the majority of other commercial strata properties and storage had patterns that were less clear.

Finally, perhaps the most intriguing actual use type for improved access to YVR is the commercial strata properties category. In Figure 6, it is noteworthy that the majority of commercial strata properties within 10 kilometres of YVR had primarily negative marginal effects, but these θ_n were relatively small. But beyond 10 kilometres, there are some strata properties with much lower values of the negative θ_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, 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. This could be because that the Canada Line allowed the hotel owner to eliminate or reduce the costs of operating a shuttle bus but also they could now deploy surplus employee parking to providing an "park, stay and fly" service thereby increasing occupancy and revenue. Once again, the patterns for the other actual use types are somewhat less clear.

To demonstrate the effectiveness of our identification strategies, 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 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 θ (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 identification strategy 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 θ are highly insignificant. Furthermore, the GWR bandwidth test has a P-value=1.000, which implies that GWR does no better than OLS. 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 β 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 identification 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 identification strategy and 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 identification strategy 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 Brighouse. It appears that faster and more reliable access to these centres enhances agglomeration economies and facilitates transactions and business' access to employment pools, which may become capitalized into many commercial property values. It is also possible that commercial property values increased in the two CBDs because owners could redeploy space allocated to vehicle parking to other uses that increase revenue and/or enhances the property's amenities. 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.[27] The 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 may have led to greater agglomeration (and higher commercial property values) in those neighborhoods outside of these two cores. Also, the

[27] Employment numbers are from Stats Canada.

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 probably reflects the high vehicle trip generation rate of hotels per unit of area relative to the other land use categories. Faster and more reliable access to hotels makes these hotels more attractive for tourists and business travelers, which makes the locations of these hotels more valuable. It is also possible that some hotels save money with the Canada Line by not having to operate shuttle buses to the airport and other locations, and these savings can become capitalized into the hotels' property values.

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 (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, Brighouse, 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, Brighouse, 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 change 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 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 that benefit from shorter travel times to Olympic Village station. This may be in part due to the

nascent nature of Olympic Village as a business activity centre and the transitory nature of activity around this station (jobs, visitors and athletes) associated with the Olympics.

Regardless of the net impacts, some of our results imply that enhanced access to some areas with the Canada Line had a substantial impact on the businesses in 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 identification strategy and 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 results for policy makers on how and where allocation of their scarce resources have been fruitful.

References

Anderson, M. L. 2014. Subways, Strikes, and Slowdowns: The Impacts of Public Transit on Traffic Congestion. *American Economic Review,* 104(9): 2763-2796.

Appold, S.J. 2015. Airport cities and metropolitan labor markets: an extension and response to Cidell. *Journal of Economic Geography* 15(4): 1145-1168.

Appold, S.J. & Kasarda, J.D. 2013. The airport city phenomenon: evidence from large US airports. *Urban Studies* 50(4): 1239-1259.

Aschauer, D.A., 1989. Is public expenditure productive? *Journal of Monetary Economics*, *23*(2): 177-200.

Bauernschuster, S., Hener, T., and Rainer, H. When Labor Disputes Bring Cities to a Standstill: The Impact of Public Transit Strikes on Traffic, Accidents, Air Pollution, and Health. Forthcoming, *American Economic Journal: Economic Policy*.

Baum-Snow, N., Kahn, M. E. 2005. Effects of Urban Rail Transit Expansions: Evidence from Sixteen Cities, 1970-2000. *Brookings-Wharton Papers on Urban Affairs*, 147-206.

Baum-Snow, N., & Kahn, M. E. 2000. The effects of new public projects to expand urban rail transit. *Journal of Public Economics*, *77*(2): 241-263.

Bifulco, R., J.M. Fletcher, and S.L. Ross. 2011. "The effect of classmate characteristics on post-secondary outcomes: Evidence from the Add Health." *American Economic Journal: Economic Policy*: 25-53.

Bilotkach, V., Gorodnichenko, Y., & Talavera, O. 2012. Sensitivity of prices to demand shocks: A natural experiment in the San Francisco Bay Area. *Transportation Research Part A: Policy and Practice*, *46*(5), 1137-1151.

Brueckner, J. K. 2003. Airline traffic and urban economic development.*Urban Studies*, *40*(8), 1455-1469.

Cidell, J. 2015. The role of major infrastructure in subregional economic development: an empirical study of airports and cities. *Journal of Economic Geography* 15(4): 1125-1144.

Cohen, J.P. and C.C. Coughlin. 2008. Spatial Hedonic Models of Airport Noise, Proximity, and Housing Prices. *Journal of Regional Science* 48(3): 859-878

Cohen, J. P., & Paul, C. M. 2007. The Impacts of Transportation Infrastructure On Property Values: A Higher-Order Spatial Econometrics Approach. *Journal of Regional Science*, *47*(3), 457-478.

Crowley, R. 1973. A Case Study of the Effects of an Airport on Land Values. *Journal of Transport Economics and Policy*, 7(2): 144-152

Damm, D., et al. 1980. Response of urban real estate values in anticipation of the Washington Metro. *Journal of Transport Economics and Policy*: 315-336.

Debrezion, G., E. Pels, and P. Rietveld. 2007. The Impact of Railway Stations on Residential and Commercial Property Value: A Meta-analysis. *The Journal of Real Estate Finance and Economics* 35(2): 161-80.

Diao, M., Qin, Y., & Sing, T. F. 2015. Negative externalities of rail noise and housing values: Evidence from the cessation of railway operations in Singapore. *Real Estate Economics*.

Duranton, G., & Turner, M. A. 2011. The fundamental law of road congestion: Evidence from US cities. *The American Economic Review*, 2616-2652.

Duranton, G. and Puga, D., 2004. Micro-foundations of urban agglomeration economies. *Handbook of regional and urban economics*, *4*, pp.2063-2117.

Fershau, J. E. 2003. *Stuck in Gridlock: Agenda-setting and Agenda Management: a Case Study of Translink-the Greater Vancouver Transportation Authority* (Doctoral dissertation, Simon Fraser University).

Fu, S., & Ross, S. L. 2013. Wage premia in employment clusters: How important is worker heterogeneity? *Journal of Labor Economics*, *31*(2), 271-304.

Huber, S., & Rust, C. 2015. osrmtime: Calculate Travel Time and Distance with OpenStreetMap Data Using the Open Source Routing Machine (OSRM). *Available at SSRN 2691551*.

Kasarda, J.D., & Lindsay, G. 2011. *Aerotropolis: the way we'll live next*. Macmillan.

Kelejian, H.H. and Robinson, D.P. 1997. Infrastructure productivity estimation and its underlying econometric specifications: a sensitivity analysis. *Papers in Regional Science*, *76*(1): 115-131.

Kim, J., and M. Zhang. Determining transit's impact on Seoul commercial land values: an application of spatial econometrics. *International Real Estate Review* 8.1 (2005): 1-26.

McDonald, J.F., and D.P. McMillen. 2010. *Urban economics and real estate: theory and policy*. John Wiley & Sons.

McMillen, D. P., & Redfearn, C. L. 2010. Estimation and hypothesis testing for nonparametric hedonic house price functions. *Journal of Regional Science*, *50*(3), 712-733.

McMillen, D. P., & Dombrow, J. 2001. A flexible Fourier approach to repeat sales price indexes. *Real Estate Economics*, *29*(2), 207.

McMillen, D. 2004. Airport Expansions and Property Values: The Case of Chicago O'Hare Airport. *Journal of Urban Economics*, 55, 627–640.

McMillen, D. P. 2003. Neighborhood house price indexes in Chicago: a Fourier repeat sales approach. *Journal of Economic Geography*, *3*(1), 57-73.

O'Sullivan, A. 2009. *Urban Economics*. McGraw-Hill.

Puga, D., 2010. The magnitude and causes of agglomeration economies. *Journal of Regional Science*, *50*(1), pp.203-219.

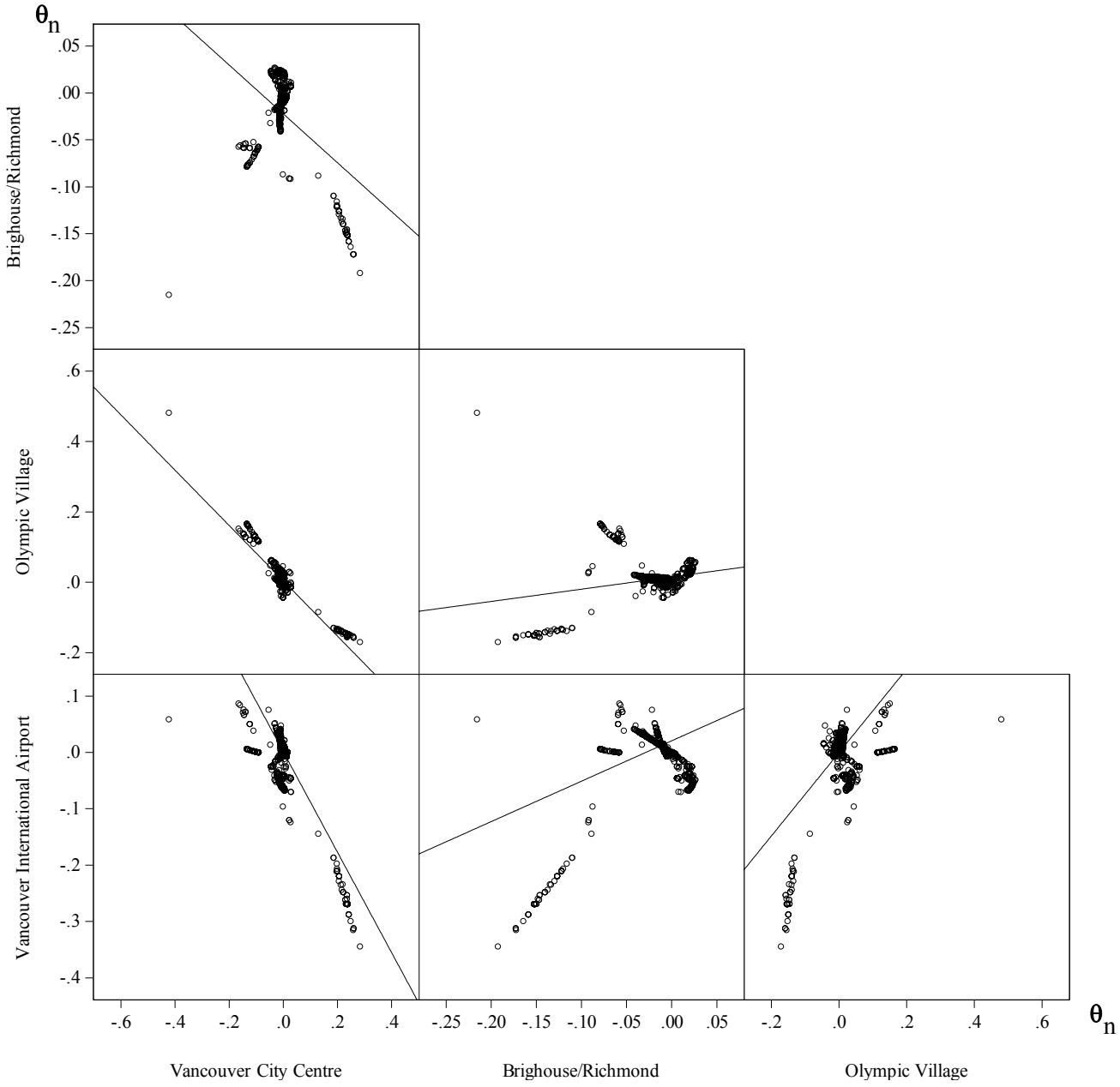
Tomkins, J., N. Topham, J. Twomey, and Robert Ward. 1998. Noise versus Access: The Impact of an Airport in an Urban Property Market. *Urban Studies*, 35, 243–258.

Winston, C. & V. Maheshiri. 2007. On the Social Desirability of Urban Rail Transit Systems. *Journal of Urban Economics* 62: 362-382.

Figure 1: Map of Canada Line Stations in Richmond, BC and Vancouver, BC

Source: Translink

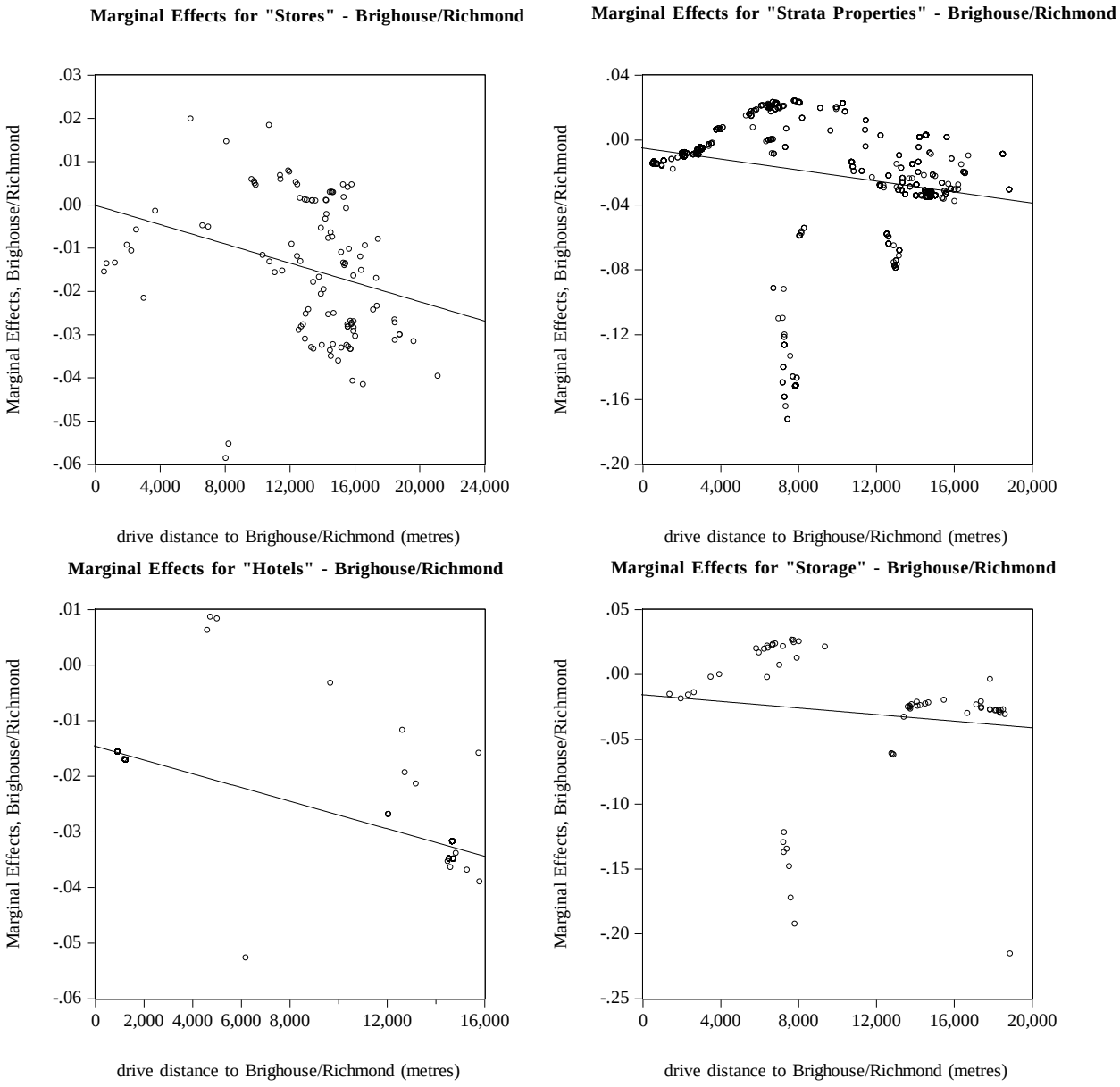
Figure 2: Marginal Effects (θ_n) of Travel Time Savings on Commercial Property Values, Travel to 4 Rail Stations (Brighouse, Vancouver City Centre, Olympic Village, YVR)



These plots are for all n=1,2,…,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 3: Marginal Effects for 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:

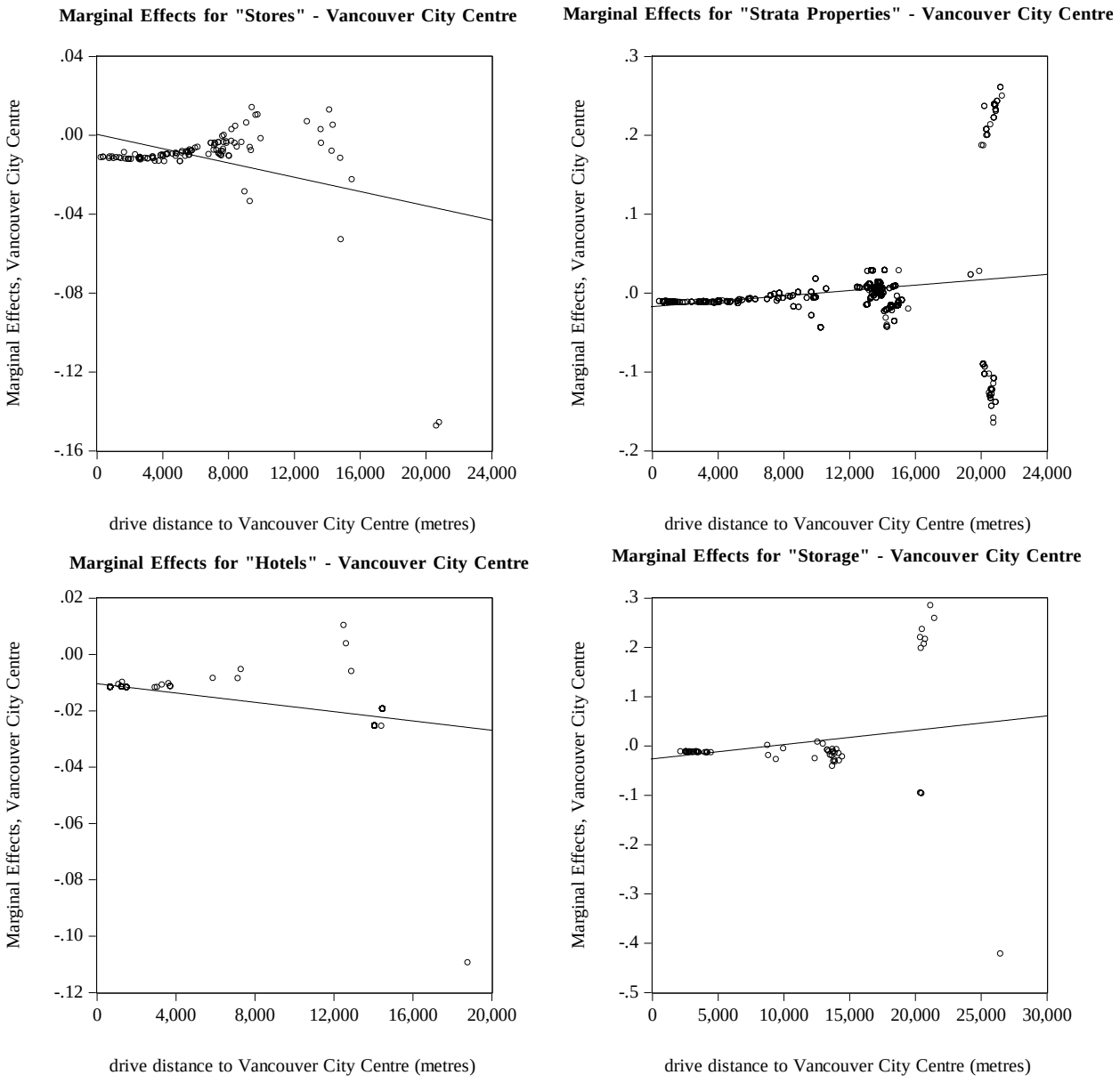
Stores: 200, 202, 204

Strata: 216 (Commercial Strata Properties)

Hotels: 230, 232, 233, 237, 239

Storage: 273 (storage & warehousing, closed)

Figure 4: 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:

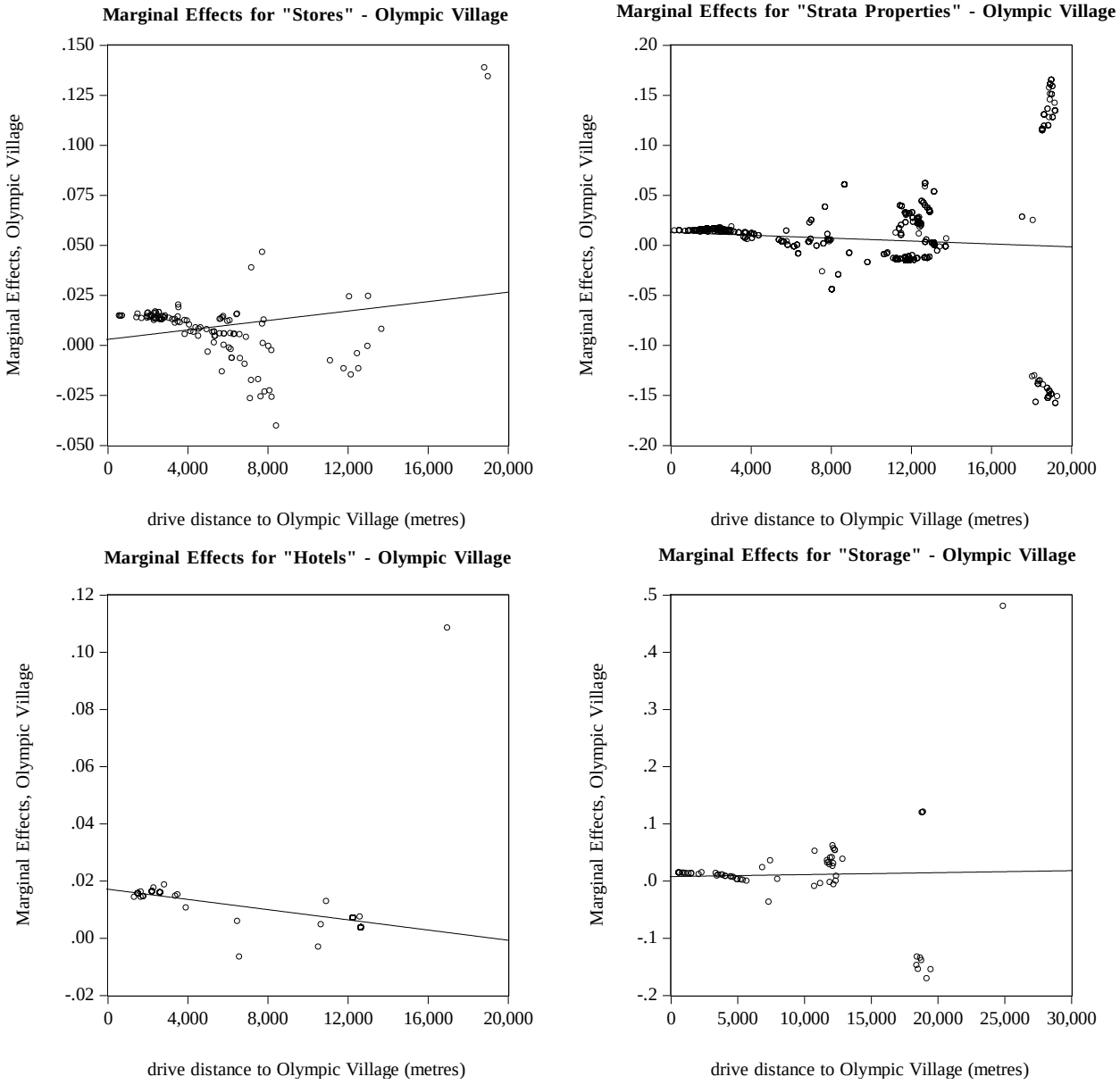
Stores: 200, 202, 204

Strata: 216 (Commercial Strata Properties)

Hotels: 230, 232, 233, 237, 239

Storage: 273 (storage & warehousing, closed)

Figure 5: Marginal Effects for 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:

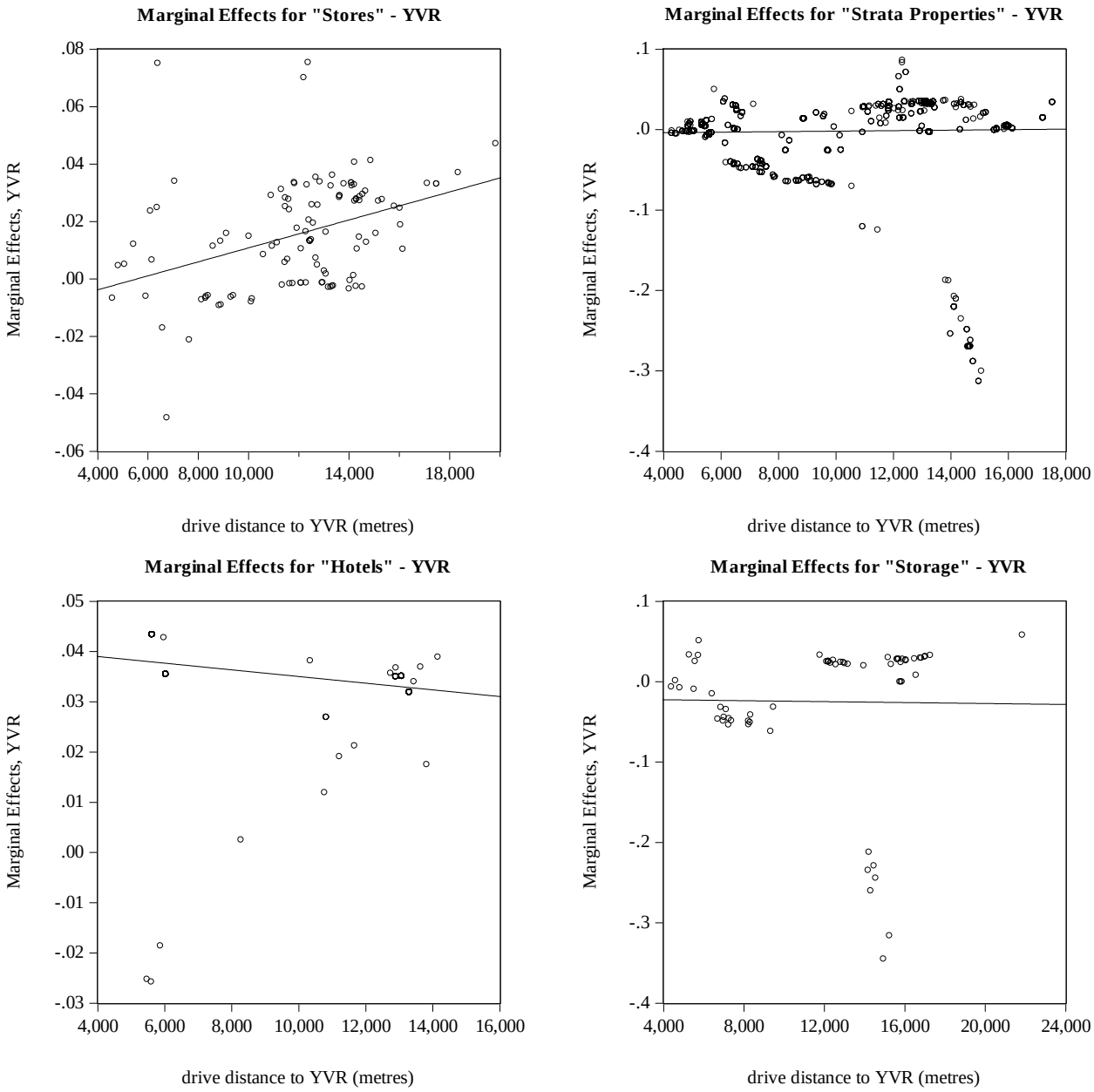
Stores: 200, 202, 204

Strata: 216 (Commercial Strata Properties)

Hotels: 230, 232, 233, 237, 239

Storage: 273 (storage & warehousing, closed)

Figure 6: 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)

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

Variable	Units	Mean	Std. Dev	Maximum	Minimum	N
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*)

	OLS, Differencing
Dependent Variable: Log of Price Ratio for the two repeat sales	
Independent Variables	
Difference in Travel Time to Brighouse	**-0.005186**
	0.2613
Difference in Travel Time to Vancouver City Centre	**-0.020113**
	0.0000
Difference in Travel Time to Olympic Village	**0.020752**
	0.0000
Difference in Travel Time to Airport	**0.004294**
	0.3852
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, θ_n from Each Commercial Property to Brighouse/Richmond Station

θ_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, θ_n from Each Commercial Property to Vancouver City Centre Station

θ_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, θ_n from Each Commercial Property to Olympic Village Station

θ_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, θ_n from Each Commercial Property to Vancouver International Airport (YVR) Station

θ_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

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

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

*ITE do not have trip generation rates for neighbourhood "Mom and Pop" convenience stores and restaurants, but since access is 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)***

	Model Specification: OLS, Differencing
Dependent Variable:	
Log of Price Ratio, Including Repeat Sales Price Index	***YES***
Repeat Sales Sample	***YES***
Independent Variables:	
Travel Time to Brighouse	**1.29E-01**
	0.341
Travel Time to Vancouver City Centre	**-5.62E-03**
	0.887
Travel Time to Olympic Village	**2.89E-02**
	0.23
Travel Time to Airport	**-0.124**
	0.418
GWR bandwidth test	**8040**
(When P-Value>0.05, GWR does no better than OLS)	*1.000*
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 Brighouse/Richmond Station
Estimation Method: OLS, including repeat sales price indexes as independent variables (estimates not shown)

Independent Variables:	**Estimate**	**P-Value**	**N**	**R-squared**
$\text{Log}(P_{n,t+j} / P_{nt})$	-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)

Independent Variables:	**Estimate**	**P-Value**	**N**	**R-squared**
$\text{Log}(P_{n,t+j} / P_{nt})$	-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)

Independent Variables:	**Estimate**	**P-Value**	**N**	**R-squared**
$\text{Log}(P_{n,t+j} / P_{nt})$	-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)

Independent Variables:	**Estimate**	**P-Value**	**N**	**R-squared**
$\text{Log}(P_{n,t+j} / P_{nt})$	-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.