Bret Allinott, MA (1500542)

allinott@ualberta.ca

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Effect of LRT Expansion on Neighbouring Properties: Evidence from Edmonton Alberta

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1 Introduction

Edmonton Alberta began Light Rail Transit ('LRT') service in 1978, with five stations operating in the central business district (City of Edmonton, ETS History). Since then, the City of Edmonton ('the City') LRT system has expanded further North and South, and as of 2022 has 18 stations across two lines (Metro and Capital Lines). Unlike a bus system, the creation or expansion of the LRT system requires a substantial investment. For instance, the initial construction of the LRT line in 1978 cost 65 million dollars or approximately 450 million dollars in 2022. Therefore, due to their high costs, a large portion of research on this issue has focused on cost-benefit analysis. However, this paper focuses on the impact of LRT expansion on surrounding communities throughout various project stages. Focusing on assessed property values, this paper maps out the effects of two stages of LRT expansion on homes of differing values and distances to the station. Understanding the effect on a property is essential, as changes in property value impact the public and the City.

For the public, a home is often the most significant investment an individual undertakes in their lifetime, and therefore changes in home prices can significantly impact a person's lifetime wealth. Intuitively, the public may support policies that raise their property prices and oppose those that might lower them. Therefore, policymakers can use property prices to approximate public sentiment. However, while a majority may follow this reasoning and are 'property-focused,' a minority of individuals may be 'transit-focused' or 'transit-opposed.' Transit-focused individuals may support the project even if it lowers property prices. In contrast, transit-opposed individuals may not support the project even if it raises property prices.[1] If LRT expansion positively affects property prices, then this can be considered a subsidy to transit-opposed individuals to

[1] I cannot estimate the size of these groups, and their sizes may lead to differing conclusions. For instance, if the LRT has a negative effect, if there is a 60/20/20 split between the property-focused, transit-focused, and transit-opposed groups, then the general sentiment for the project is negative. However, if the split is 30/60/10 and the reduction in property price is minimal, then public sentiment may be positive. Therefore, results can only conclusively suggest an increased or decreased incentive for the project.

support the project and therefore only serves to make these projects more attractive to the public. This increase in public sentiment makes LRT projects more attractive to elected officials and more likely to be built in the future. Therefore, understanding the impact of these projects is critical to monitoring public sentiment and the future viability of these projects.

It is also important to remember that the City's revenue source, land taxation, is based on this assessed property value (City of Edmonton, Property Tax). As mentioned previously, the costs of these expansions are high; therefore, if these stations elicit a positive effect, then this higher tax revenue is another benefit the City may consider. Importantly, the City typically only pays for a portion of the project but will earn the entirety of the increased land taxation. For the Valley Line South East, the City pays 800 million of 1.8 billion (City of Edmonton, Future LRT). Higher land taxation revenue for the City comes from higher assessed values and tax rates. Higher assessed values increase the homeowners' tax burden but only represent a fraction of the increase in value. Finally, since 2012, the Edmonton Municipal Mill rate[2] has increased from 15.2 to 20.0 in 2021 (Province of Alberta, Mill Rate). Multiplying the assessed price by the mill rate and dividing by 1000 gives the property tax total. Therefore for a 300,000 dollar home, this change in property tax rate amounts to about a $\$1500$ price increase.[3] However, a conservative 5% uplift in value would lift the value of the home by $\$15,000$.[4]

Finally, the benefits or costs to these stations are unlikely to be homogeneously distributed and will likely vary over time. This paper focuses on the distribution of these benefits by property value, distance to the added stations, and project stage. For instance, expensive properties may not experience a significant boost in value if the homeowner or potential buyers are not transit-focused. Similarly, otherwise identical prop-

[2] Amount of tax payable per dollar of the assessed value of a property, in 'mills,' with one mill equalling $\$0.0001$.

[3] From $\$4,650$ to $\$6,000$.

[4] Note that the increases in property tax rate are not solely resulting from the LRT expansions.

erties that are differing distances away from the station will receive differing effects. Finally, homes may experience differing effects based on whether the project is in the planning, announcement, construction, or opened phase.[5] My results indicate a significant difference in the treatment effect for homes of differing price and distance, as well as during different project stages.

2 Literature Review

First, I focus on studies using ordinary least squares to link LRT access and property prices. In 2019, Tehrani et al. surveyed various literature across the United States, finding that in many jurisdictions, there exists a significant link between LRT proximity and home prices. They also found that LRT expansions increase population density and investment within the area. The relationship between LRT access and housing prices was predominantly positive. However, in certain parts of the United States, such as Atlanta, Georgia, homes close to stations experienced a negative effect. The authors suggest that crime and noise might explain this anomaly. Their paper focused on how LRT expansion is a method of gentrification and therefore enforces segregation across income levels. The primary mechanism was how added LRT stations increased property and rental prices, making these neighbourhoods unaffordable to poor individuals and attractive to wealthier ones. LRT expansion significantly affected neighbourhood compositions, generally increasing the share of white individuals and increasing wealth and education.[6] Some jurisdictions, like Portland, Oregon, saw 'counter-gentrification,' leading to decreases in income and increases in the poverty level. Focusing on Canadian results, Bajic (1983) found a correlation between subway access and higher property prices in Toronto. In particular, he further suggests that access to the subway offers a lower transportation cost to individuals and that the higher property costs equal the reduction in transportation costs. My paper

[5]This paper only considers the construction and opening phases due to data availability.

[6]Higher wealth and education resulted from an outflow of poorer individuals and an inflow of wealthier, more educated individuals.

attempts to provide similar insights into inequity, given data availability, by analyzing how these added stations impact homes of different properties. Looking into projects of various stages and coupling it with an analysis of distance offers a more detailed effect of the inequity than the one provided by Tehrani et al., as they only looked at the opening phase. Bajic had access to data that presented commuter costs, while I did not. Therefore, I only utilize his paper as a potential mechanism for price increases.

Next, I focus on papers that utilize difference-in-difference or similar methods to establish causal links. Regarding project timings, Johnson and Nicholas (2019) analyze the effect of an LRT station announcement on property prices in the Kitchener-Waterloo area. First, they looked at repeat home sales (same home, different sales) before and after the announcement and found that homes around the LRT stations increased in value faster than other properties. As a second method, they utilized a difference-in-difference hedonic pricing model, similar to the one I will discuss in the econometric model's section. Their second method suggests a minimal impact on property prices and that only condominiums experience a positive effect, but that this effect was present before the LRT system. Also, any significant impacts of LRT access only occurred at around a 1-kilometre radius of stations. In 2011, Billings utilized the unique characteristics of an LRT announcement in Charlotte, North Carolina, to determine the effect of added stations. A subset of homes gained access to a new LRT line, while another group of homes were on LRT lines that were announced but never built. Since this feature is not present in Edmonton, I utilize distance to stations to create experimental groups. These papers focused on the announcements stage and only looked at the average impact. My paper expands these results by maintaining their causality while adding an analysis of effects over different stages, values, and distances.

3 Policy Review

As of 2022, the City has 18 open LRT stations, with plans to add 39 stations (City of Edmonton, Future LRT). Announced in 2012, the Valley Line will add 25 of these 39 stations as well as 27 kilometres of new track and the newly constructed Tawatinâ Bridge over the North Saskatchewan River. The Valley Line was estimated to cost 3.5 billion 2016 Canadian Dollars and comprises two sub-projects; Valley Line West and Valley Line South East ('SE'). The Valley Line SE represents 13 kilometres of new track, features 11 stops, and has a projected cost of 1.8 billion Canadian Dollars. Construction on the Valley Line SE began in the Spring of 2016 and is expected to finish by Summer 2022. Valley Line West began construction in 2021 and will take 5 to 6 years to complete. The remaining 14 of 39 stations are added by expansions to the City's current Capital and Metro lines, expanding the system further South and North. No public announcements have been made regarding the specific location of these 14 stations, as these projects are in the early stages; therefore, they are not the focus of this analysis. The Valley Line SE's construction phase will be the first project type explored in this paper.

Next, I want to focus on the opening phase. Since none of these planned stations are operating, I utilize the 2015 expansion of the Metro Line (City of Edmonton, ETS History). This expansion added the MacEwan, Kingsway, and Northern Alberta Institute of Technology ('NAIT') stations to the Metro Line. These popular stations connect the LRT system to two colleges, a shopping centre, and the largest arena in Edmonton, Rogers Place. Rogers Place's construction was complete in September 2016, and MacEwan station, the nearest of the three, opened a year previously in September 2015. Since Rogers Place was under construction at the time of MacEwan stations opening, it is likely that homes in the MacEwan area experienced a benefit from the LRT and Rogers Place. Therefore I control for the distance from Roger's place in the analysis. Section 5, econometric methods, will further outline the analytical approach.

4 Theoretical Framework

The addition of an LRT station to nearby properties is a demand shock. All else equal, adding LRT stations should create a positive demand shock, raising prices. There are a variety of avenues in which added stations could increase demand. Firstly, added stations may reduce congestion (Bhattacharjee and Goetz, 2012), reducing travel times and benefiting those who may not use the LRT. Second, for those that utilize the LRT, it can often lower transportation costs. The current monthly, unlimited usage pass is $100 (City of Edmonton, Fares and Passes), and depending on commuting distance may be cheaper than travelling by car. Finally, as mentioned in Tehrani (2019), additional stations make communities more accessible and increase capital investment. This additional capital can result in new businesses in the area, bringing people and money into the neighbourhood. Therefore, all else equal, a reduction in congestion, lower transportation costs, and better community access should increase demand for the area and raise home prices. However, several factors can offset these price increases.

Firstly, there are additional concerns which may temper the demand shift. Community access is a two-way street, and many researchers have observed links between LRT proximity and higher crime rates. Research by Azad in 2011 demonstrated that for various Calgary LRT stations, crime was either statistically higher or lower after the station opening. This result indicates a large variability in crime occurrence across the same transit line. However, if crime rises significantly, this should make the neighbourhood less safe and more likely to incur property damage, which will bring demand back down. Another factor which may temper demand is an increase in noise levels. The LRT will undeniably increase the noise in the neighbourhood, so unlike crime, it is simply a question of how negatively this will impact valuations.

Next, the last method that can offset price increases are changes in supply. If the net effect on demand is positive, home builders may begin building homes in the area to capture some of this increased market interest. If supply increases substantially, then there may not be a detectable effect (through increased price), even though the new station does increase demand. Housing supply will be a delayed effect, as unless home builders are forward-looking, they must observe increased demand, secure land and construct homes, which may take several years. Therefore, the best way to isolate the demand effect is to estimate the effect immediately after treatment, before the supply can adjust. However, public expectations may also be lagged, and therefore a variety of periods is included in the analysis.

The COVID-19 pandemic is likely to include both demand and supply shocks, and as these factors can alter the treatment effect, these years are omitted from the analysis. The accompanying recession would likely temper demand, and the health measures undertaken may impact the housing supply levels.

Finally, I cannot observe the rental market due to limited availability. The rental market is likely to undergo similar effects as the housing market, so results should generally move together (higher assessed values would likely mean higher rents), but this should be explored in future work.

5 Econometric Models

As mentioned in the policy review section, this paper focuses on two different lines and their respective project stages. Firstly, homes near the Valley Line SE experience the project's construction phase. Secondly, homes near the Metro Line extension experience the opening phase. For the two treatments, I designated the treatment groups as properties within 1 kilometre ('as the crow flies') of either the Valley Line SE station or the Metro Line extension. I chose the 1-kilometre radius for a variety of reasons.

First, the results from Johnson and Nicholas looking at the impact of new stations found significance only in a radius of approximately 1 kilometre. Secondly, I seek to limit heterogeneity in access methods. For instance, if the radius expands, certain individuals may be able to take advantage of rapid or optimized bus routes, while others cannot. Therefore, 1 kilometre seeks to minimize individuals to a mostly walkable range, such that everyone within each band of distance has equal accessibility.[7] Finally, the 1-kilometre distance allows a significant difference between the treatment and control groups. I designated the control group as all properties that are a set distance from any open or planned LRT station. I chose the distance that led to an approximately equal-sized control and treatment group. For the Valley Line construction model, this was 6.5 kilometres from any open or planned station. For the Metro Line extension opening, this was 7.6 kilometres. If the treatment area is made larger, the distance between any station type for the control group must be smaller. Therefore, moving the experimental groups closer and making the treatment effect harder to detect.

I utilize two different methods to determine the treatment effect. Section 5.1 discusses a quantile difference in difference approach. This approach assigns a binary variable to the control and treatment groups and assumes the treatment effect throughout the group is homogeneous. A quantile regression approach analyzes how the treatment varies over different property values. Section 5.2 addresses the binary treatment effect assumption by utilizing a continuous treatment, enabling an analysis of how the treatment varies over distance. Together, these two models outline how the treatment effect varies by project type, property value, and distance to the station.

5.1 Quantile Difference in Difference

To capture the treatment effect over differing property values, I utilize the difference in difference model presented in equation 1. I estimate equation 1 for three sub-samples and three percentiles. The first sub-

[7] That is, all people at the 600 metres distance, for instance, experience roughly the same commute and commute time to the station.

sample will contain observations from the year before and year of the policy, the second will contain observations from the year before and the year after the policy, and the final model will be a full sample, running from 2012 to 2019.[8] Finally, quantile regression estimates each period's coefficients at the 25th, 50th, and 75th percentiles of assessed values.

$$\ln(\text{Price}_{it}) = \beta_0 + \beta_1 \text{Treatment}_{it} + \beta_2 \text{Time}_{it} + \beta_3 (\text{Treatment}_{it} \cdot \text{Time}_{it}) + \beta_4 \text{Controls}_{it} \quad (1)$$

The dependent variable is the log-transformed real assessed value. The coefficient β_1 captures differences between the treatment and control groups before treatment. Coefficient β_2 represents time effects common to both experimental groups. Finally, β_3 represents the treatment effect; the effect only felt by the treatment group. A positive and significant coefficient would suggest that homes nearby the station experienced a positive impact by being near the LRT station. Controls[9] common across both models are apartment and garage indicators, lot size, structure size, year built, distance to the central business district ('CBD')[10], distance to not yet open or constructed Valley Line West stations[11] and levels of theft in a neighbourhood. For the Valley Line South East models, the distance to an open LRT station (including the metro extension) is included, and for the Metro Line extension, the distance to the Valley Line South East is included. Finally, to control for the addition of Rogers Place around the MacEwan area in 2016, distance to Rogers place is included only for the Metro Line model. Assessment year is used as a trend term for the full sample models. I used bootstrapped standard errors for robustness, and I performed 20 repetitions. While this is relatively low, the large number of observations ensured that the significance of the results was not sensitive to the number of repetitions.

[8] Utilizing multiple periods allows for an understanding of how this affects assessed values over time.

[9] Section 6 contains more information on controls and their construction.

[10] Defined as Edmonton City Hall. Holian 2019 demonstrates that a city's city hall often outperforms more complex methods for determining the central business district.

[11] Controls any impact the announcements stage may have and I also used it to define the control group.

5.2 Continuous Treatment: Dosage

The dosage model constructs a 'dosage response function,' which maps out the average treatment effect ('ATE') as the distance to the station varies. To estimate the dose-response function, I utilize the stata command, ctreatreg, created by Giovanni Cerulli (2015), which is an improvement to a method proposed by Bia and Mattei in 2008. Continuous treatment is handled by including a response function, $h(t)$, to the treatment model. Those with a positive level of treatment, $t > 0$,[12] are put into the treatment group ($T = 1$), and those with $t = 0$ are in the control group ($T = 0$). While the dosage approach would be able to address a few concerns about the treatment area discussed earlier[13], expanding the treatment group would still make treatment harder to detect. If I expand the distance, its comparability to the difference-in-difference model is lost. Therefore, I continue to utilize a 1-kilometre treatment group. Equation 2 presents the model form for each experimental group.

$$\ln(y_{it}(T)) = \begin{cases} \ln(y_{it}(T=1)) = \mu_1 + \beta_1 X + h(t) + \varepsilon_1, & \text{for } t > 0 \\ \ln(y_{it}(T=0)) = \mu_0 + \beta_0 X + \varepsilon_0, & \text{for } t = 0 \end{cases} \tag{2}$$

Where μ_T represents experimental group-specific means, and β_T represents the set of coefficients for each experimental group. The dosage models utilize the same set of controls as their respective difference in difference model, except it does not contain a treatment interaction term, as this is handled by $h(t)$. Again, $h(t)$ is a response function to the dosage (distance to the station) and is assumed to have the parametric form presented in equation 3.

$$h(t) = at + bt^2 + ct^3 \tag{3}$$

[12] Those within 1 kilometre of their respective stations.

[13] Namely, the results of Johnson and Nicholas and heterogeneity in access.

The parameters a, b, and c are estimated through ordinary least squares. Finally, equation 4 presents the average treatment effect for both experimental groups.

$$\underbrace{E(\ln(y_{it}(T=1) - \ln(y_{it}(T=0))}_{\equiv ATE(t)} = \begin{cases} \underbrace{(\mu_1 - \mu_0) + \bar{X}_{t>0}\beta + \bar{h}_{t>0}}_{\equiv ATET} + (h(t) - \bar{h}_{t>0}), & \text{for } t > 0 \\ \underbrace{(\mu_1 - \mu_0) + \bar{X}_{t=0}\beta}_{\equiv ATENT}, & \text{for } t = 0 \end{cases} \tag{4}$$

Where $\bar{h}_{t>0}$ is the average dosage in the experimental group, and $\bar{X}_T$ is the average value of the controls for each experimental group. ATET represents the average treatment effect of the treatment group, and ATENT represents the average treatment effect for the control group. The average treatment effect for the control, $ATE(t)_{t=0}$ is a scalar and does not vary in t. However, the average treatment effect for the experimental group, $ATE(t)_{t>0}$, is a continuous function in t through the response function, $h(t)$. Graphing $ATE(t)_{t>0}$ over the dosage level yields the dosage response function. I used bootstrapped standard errors as a robustness measure. Once again, I used 20 repetitions, but due to the number of observations, there was no noticeable impact on the dosage response function.

5.3 Endogeneity

Due to the treatment definition, the neighbourhood variable cannot be included in either the quantile or dosage approaches and may introduce endogeneity through omitted variable bias. Some neighbourhoods lie within the 1-kilometre radius around the station, so the neighbourhood variable is perfectly collinear with the treatment. Next, while some neighbourhoods lie on the boundary, only homes within the 1-kilometre radius in that neighbourhood are included in the treatment group and not in the control group. While not all homes in the neighbourhood are within the 1-kilometre radius, homes outside are not included in the estimation. Therefore, the neighbourhood is once again perfectly collinear. The neighbourhood factor variable would control for various neighbourhood characteristics, such as average income level, education, amenities, and crime. I cannot control most of these due to data availability, but I utilize a neighbourhood crime estimation to limit this potential endogeneity as much as possible. If the neighbourhood indicator's only effect was through crime, then endogeneity is likely to be avoided by including my crime term, but this is unlikely. Therefore, I would need data on household incomes, education levels, and other factors to further reduce the odds of endogeneity.

6 Data

Since 2012, the City has provided an assessed value and several property characteristics,[14] for each property within Edmonton (City of Edmonton, Property Assessment Data). While data is available for 2020 through 2022, I exclude these years to remove any complications that the COVID-19 pandemic might introduce.[15] As outlined in the theoretical framework, this treatment is particularly sensitive to demand and supply shocks, and therefore COVID-19, which likely impacts both, may introduce errors. The assessment data is an annual measure representing your home's assessed value on July 1st of the previous year.[16] The housing market likely adjusts more frequently; therefore, this assessed value only provides a snapshot of the year's movement. If the market has a consistent and seasonal pattern, these snapshots are comparable, and the impact on analysis is minimal. However, if there are unpredictable fluctuations and one year's snapshot is 'high' while another is 'low,' this may bias the treatment effect estimation.

I construct the distance variables by utilizing the properties coordinates. Using coordinates of City hall and Rogers Place, I calculate the distance of every property to these locations using the haversine formula. Utilizing tables of LRT stations, I can similarly calculate the haversine distance of each property to the nearest LRT station of varying types (City of Edmonton, LRT Locations). Specifically, I find the distance to the

[14] Variables such as lot size, year built, a garage indicator, geographic coordinates, neighbourhood and assessment class.

[15] While the 2020 assessment year contains property values as of 2019 (discussed shortly), there may be institutional changes within the City, due to COVID-19, that may cause differences in measurement, so I remove this year as well.

[16] For instance, an assessed value in the 2017 assessment year represents the home's value on July 1st, 2016.

nearest open station, Valley Line SE, and Valley Line West. I construct the apartment/condo indicator by assigning these properties a 1 if they contain a suite number.

The assessment data only contains lot size and not the size of the structure. Therefore, I utilized current calendar year property information, which is collected separately (City of Edmonton, Property Information). These structure sizes are only accurate for the current year; thus, houses that have added extensions within the sample period will have periods with an incorrect structure size. This error will introduce attenuation bias and bias coefficients towards zero. However, results indicate that this variable is highly significant[17], and this may suggest that overall measurement error is minimal and random and therefore would have minimal impact on the estimation of coefficients.

To construct the theft variable, I utilized monthly data on occurrences of various crime types by neighbourhood (City of Edmonton, Neighbourhood Crime Occurrences). I then collapse this monthly data into annual totals. I then match this data to the property's neighbourhood to get the number of various crime types committed in the property's neighbourhood for that assessment year. Next, I add all the robberies, breaking and enterings, and thefts of/from vehicles to construct the theft variable. To construct the violent crime variable, I add all the assaults and sexual assaults.[18,19] Finally, to account for neighbourhood size, I divide these total incidents per neighbourhood per year by the total number of properties in that neighbourhood and year.

To focus on homeowners, I limit the data to residential properties. I omit properties that do not have

[17] In fact, one of the most significant

[18] Homicide is not included as most of the homicide observations in the data were not attributed to a particular neighbourhood.

[19] Violent crime is only used as a summary measure, as it was less significant in analysis than the theft variable, and when used together in the quantile method, the model was not able to be estimated in some cases, due to high correlation between the two.

measurements for the log-transformed real price, lot size, structure size, distance to an open LRT, or year built. I also omit properties with structure and lot sizes lower than 10 square metres and properties that cost less than $10,000. I omit these properties as they are either measurement errors or are small, likely uninhabitable lots that do not contain a residence. Since they are unlikely to contain a proper residence, it is doubtful that these properties represent significant portions of the owners' wealth and, therefore, would have minimal impact on their incentives.

Table 1 presents summary statistics for the entire sample and the experimental groups for the Valley Line SE and Metro Line models.[20] There are common features to both stages and their respective experimental groups. As expected, the control groups are similar, as they only differ by how far they are from any open or planned LRT. However, while both treatment groups are in different parts of the City, they share similarities. The experimental groups have lower valuations, are more likely to have apartments and less likely to have garages, have smaller lot and structure sizes, and have older buildings compared to the control groups. Both experimental groups also have higher incidences of theft and violent crimes, with the Metro Line experimental group being particularly high. This higher crime occurrence may result from the Metro Line being much closer to the city centre. Finally, once built, a Valley Line (SE and West) will be the nearest station for 45% of properties within my sample.

7 Results and Policy Implications

7.1 Difference in Difference Models

Table 2 presents the estimation results for the Valley Line SE construction phase. Only a subset of variables used in the estimation is presented. Since the project began in 2016, 2017 is used as the treatment year due to the lagged nature of the data. The first column (containing only the year before and of the treatment) of

[20] I discussed designation of the experimental groups previously in the econometric models section.

table 2 suggests an immediate treatment effect, ranging from approximately 1.5% to 2.5%. Since supply is unlikely to adjust this quickly, this time period will most likely represent the pure price increase caused by the added station, causing a positive demand shock. The second column (containing only the year before and after treatment) has a treatment effect ranging from 1% to 2.2%, suggesting that perhaps there was some movement in the housing supply. It is unlikely that a significant number of homes could have been added in a year, so if supply is causing this reduction, this would be caused by forward-looking home builders that started construction before the treatment effect. Finally, the full sample treatment effect varies from 2.2% to 4.2%. One explanation for this increase could be caused by 2015 being an exceptionally high year for assessment values and, therefore, a poor reference point. Another is that demand only jumped part of the way and only got stronger as the project progressed. Finally, supply may have been lowered (or not grown quickly) over these additional years. The final sample results suggest an inequity between the 25th percentile homes ($193,338.2) and 75th percentiles ($313,148.8) in their treatment effect magnitude. I offer two explanations for this. From table 2, we see that higher crime levels have a much higher, negative impact on the 25th percentile homes compared to the 75th percentile. If the stations increased the crime level, this higher sensitivity at the lower end of the price spectrum would decrease their demand more than the high-value homes. However, this is unlikely, as the stations were only in the construction phase, and intuitively that does not seem likely to increase crime. Therefore the remaining explanation is supply. Figure 1 maps out the treatment group's total number of homes in the lower 25th ($164,921.5 and lower) and upper 75th percentiles ($283,844.4 and higher). The supply of homes in the lower 25th grew, and the number of homes in the upper 75th shrunk from 2016 onwards. This inequity in supply could explain the inequity in the treatment effect.

Table 3 presents the estimation results for the Metro Line opening phase. Once again, only a subset of variables is presented. The Metro Line stations opened in 2015; therefore, I use 2016 as the treatment year due to the one-year lag in the data. The first column (containing only the year before and of the treatment) indicates no significant effect of the treatment. Either expectations are adjusting more slowly, or perhaps home builders are more proactive and are already deploying higher supply levels. Moving to column two (containing the year before and after treatment) leads to strong treatment effects in the 50th and 75th percentiles of 4.3% and 9% respectively, but no significant effect on the 25th percentile. Finally, the treatment effect varies in the full sample from -1.8% to 6.7%. Once again, there are substantial differences between homes in the 25th percentile ($163,051.6) and the 75th percentile ($321,107.3). Unlike the Valley Line model, there does not appear to be a significant difference in the theft coefficient across percentiles, suggesting all properties feel a similar effect to crime. Figure 2 presents the treatment group's total count by properties for the lower 25th ($97,606.59 and lower) and upper 75th percentiles ($215,960.7). Once again, the lower 25th has a higher property increase post-2016, while the upper 75th declines. For the 50th and 75th percentiles, the opening phase elicits a stronger treatment effect than the construction phase, yet it is harmful to the 25th percentile. One possible explanation comes from the differences in the project stage. The Valley Line SE is only undergoing construction and therefore is unlikely to increase the crime levels; consequently, the primary mechanism to counter the positive demand shock is increased supply. However, the Metro Line is open and may raise the crime rate. This potential crime increase occurs alongside the increased supply. If crime is more likely to happen at/around these poorer properties than rich ones, then increased crime and higher supply may explain the inequity and negative treatment effect.

7.2 Dosage Models

Figure 3 presents the dosage response function for the Valley Line SE construction phase. A zero dosage represents homes on the edge of the treatment group, or about 1 kilometre away. A dosage of 100 is given to the home closest to the station, about 15 metres away. The shape is unique, indicating that as homes move closer to the station, they experience a decreasing treatment effect, with an overall negative impact on homes about 50 metres from the station. This result can be intuitively explained by construction-related nuisances such as noise. Homes further away don't receive these nuisances but aren't as close to the station once it opens. It appears that homes about 300 metres away are in a sweet spot, where the nuisance is minimal and distance, once it opens, is attractive. The overall impact in the 600 metres to the 1-kilometre range is negative and exhibits an odd shape. One would expect that moving from the peak at 300 metres, there would be a more linear decline in treatment (and overall a positive impact over these dosages). One explanation is that neighbourhoods in this distance band may be value-lowering, and since I cannot control these effects, I offer the perplexing dosage response shape present. With a treatment effect ranging from about -7% to 14%, these values align with the quantile approaches range, which varied from 1.1% to 4.2%.

Finally, figure 4 presents the dosage response function for the Metro Line opening. The magnitude of these results is quite odd, as homes primarily experience a negative treatment effect. Only homes about 100 metres and closer feel a positive impact of these added stations. Looking at the incidences of crime in the Metro Line treatment group in table 1, both the theft and violent crime variables are much higher than in the case of the Valley Line. While this is controlled in analysis, these high crime indicators may be correlated with lower neighbourhood income, education levels and other factors which are not controlled. Another factor is that the difference in difference model controls are only advantageous if these variables change over time. If the education and poverty levels are relatively constant over time, then this is controlled for in the analysis and not in the dosage model. Therefore, the dosage model is more sensitive to these potentially adverse effects these neighbourhoods experience. However, while the magnitudes may be puzzling, the overall shape is somewhat promising. Unlike the Valley Line, where the closest homes experience construction nuisances, this is a temporary effect not faced by Metro Line owners nearby the station. It was a possible result that the Metro Line would share the same overall shape (with the closest homes having lower treatment effects) since crime may increase specifically around the stations, but this does not seem accurate.

7.3 Policy Implications

The difference in difference and dosage approaches lend validity to the idea that LRT access increases assessment values. While there are some adverse effects, these can potentially be explained by supply increases, negative demand shocks, or a lack of sufficient neighbourhood controls. Therefore, since all else equal, these stations likely increase property values; this gives individuals throughout the City incentives to push for LRT stations nearby their properties. Likewise, for the City, this boost in assessment values will add revenue and aid in paying for these projects. Together, this incentivizes both the City and the public to expand public transportation within Edmonton in the future.

8 Conclusion

Overall, the difference-in-difference approach identifies a positive treatment effect for both the Valley Line and Metro models. The Valley Line has an inequity between the impact on the 25th and 75th percentiles, but a rapidly growing supply may explain this at the 25th percentile. For the Metro Line, the 50th and 75th percentiles felt positive effects while the 25th received negative treatment. This result may be explained by a higher crime level and an increase in the 25th percentile supply levels. The dosage model for the Valley Line shows a lower treatment effect for homes nearby the station, suggesting these homes may experience a construction-related nuisance. Finally, for the Metro Line dosage model, the overall impact is mainly negative but indicates that homes nearest the station receive the strongest and positive effects.

The most significant limitations of this paper result from data availability. Firstly, neighbourhood and homeowner level factors cannot be controlled for and may introduce endogeneity. Secondly, structure size is unlikely to be accurate for every house throughout the sample. If there is a systematic and consistent error, then results will suffer from attenuation bias, biasing them towards zero. There is also an inability to control for a variety of other treatments properties may experience. For instance, the construction of Rogers Place is significant and noticeable, but more minor effects like an added park, neighbourhood renewal projects, or other factors could also influence demand. Finally, as mentioned in the introduction, property values cannot perfectly model public incentives regarding these projects, and therefore I can only conclude that these results incentivize future LRT projects.

Possible extensions include, following ideas proposed by Tehrani (2019), the effect on neighbourhood level variables such as racial demographics, income levels, and education. As well, including the announcements phase, as done by Johnson and Nicholas (2019) for an Edmonton LRT project, will help determine when exactly valuations and, therefore, public expectations and incentives begin to change. Finally, once open, the Valley Line SE opening phase can be modelled and compared to the Metro Line opening phase. This extension can help determine whether the lower treatment effect near the Valley Line stations is a temporary construction nuisance or a feature of the Valley Line specifically. Finally, as mentioned in the theoretical framework, I cannot analyze the rental market. While similar, subtle differences between the two might indicate that renters and homeowners experience different effects of this policy.

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9 Tables

Table 1: Mean and Standard Deviation For Key Variables, by Subgroup and Treatment

	Valley Line Construction		Metro Line Extension		Full Sample
	Control	Treatment	Control	Treatment	
Real Price	308,507.69	240,776.13	378,859.91	170,043.87	260,033.02
	(188,677.55)	(150,264.64)	(298,841.38)	(96,970.64)	(155,414.74)
Garage	0.80	0.50	0.89	0.39	0.68
	(0.40)	(0.50)	(0.32)	(0.49)	(0.47)
Apartment/Condo	0.16	0.42	0.13	0.55	0.25
	(0.36)	(0.49)	(0.33)	(0.50)	(0.43)
Lot Size	1,492.07	338.37	4,926.40	266.99	493.25
	(18,365.21)	(318.62)	(37,571.66)	(253.18)	(4,714.59)
Structure Size	191.95	130.97	229.87	107.65	155.63
	(115.29)	(116.54)	(161.44)	(76.45)	(92.88)
Year Built	2002.73	1976.94	2009.37	1968.98	1984.14
	(14.03)	(22.07)	(10.55)	(27.61)	(21.98)
Distance to City Centre	12.48	4.72	14.05	1.53	8.45
	(2.95)	(3.70)	(2.93)	(0.69)	(3.88)
Distance to Open LRT	7.38	3.14	8.28	0.61	4.40
	(1.05)	(2.11)	(1.08)	(0.23)	(2.67)
Distance to Valley Line SE	11.12	0.61	12.40	1.59	6.07
	(1.50)	(0.24)	(1.73)	(0.78)	(3.55)
Valley Closer	0.05	0.86	0.06	0.21	0.45
	(0.21)	(0.35)	(0.23)	(0.41)	(0.50)
Theft Per Property	0.02	0.06	0.02	0.18	0.04
	(0.09)	(0.06)	(0.15)	(0.07)	(0.14)
Violent Crime Per Property	0.01	0.05	0.04	0.17	0.02
	(0.80)	(0.07)	(1.77)	(0.11)	(0.20)
Observations	123,461	138,015	25,314	24,851	2,164,810

Note: Standard deviations are in parenthesis. Treatment are within 1 kilometre of their respective LRT stations. Controls are properties far from open or planned stations. Real price is given in 2002 Canadian dollars, deflated using a shelter specific price index. Apartment/Condo is a dummy variable if the property has a suite number. Lot and structure size are given in square metres. All distance variables are given in kilometres and calculated using the Haversine formula. City centre is defined as Edmonton City hall. The Valley Line closer variable indicates if a property will be closer to a Valley Line station than an existing station. Theft per property equals the total number of robberies, breaking and enterings, and thefts of/from vehicles in a year and neighbourhood, and divides it by the number of properties in that neighbourhood and year. Violent crime uses the same format, but uses the sum of assaults and sexual assaults.

Table 2: Quantile Difference in Difference Results: Valley Line SE Construction

Dependant Variable: ln(Real Price)	2015 and 2017 (1)	2015 and 2018 (2)	2012-2019 (3)
25th Percentile:			
Treatment·Time	0.0267***	0.0113***	0.0224***
	(0.00273)	(0.00393)	(0.00185)
Apartment	-0.0628***	-0.0820***	-0.0733***
	(0.00348)	(0.00470)	(0.00211)
ln(Lot Size)	0.102***	0.107***	0.106***
	(0.00237)	(0.00329)	(0.00144)
ln(Structure Size)	0.641***	0.654***	0.639***
	(0.00433)	(0.00567)	(0.00245)
Theft per Property	-1.629***	-1.738***	-1.609***
in Neighbourhood	(0.0595)	(0.0884)	(0.0341)
50th Percentile:			
Treatment·Time	0.0142***	0.0121***	0.0304***
	(0.00236)	(0.00331)	(0.00131)
Apartment	-0.0420***	-0.0522***	-0.0378***
	(0.00366)	(0.00471)	(0.00299)
ln(Lot Size)	0.124***	0.130***	0.126***
	(0.00324)	(0.00440)	(0.00156)
ln(Structure Size)	0.596***	0.604***	0.600***
	(0.00366)	(0.00655)	(0.00174)
Theft per Property	-0.811***	-0.775***	-0.771***
in Neighbourhood	(0.0759)	(0.146)	(0.0438)
75th Percentile:			
Treatment·Time	0.0193***	0.0222***	0.0421***
	(0.00347)	(0.00306)	(0.00141)
Apartment	-0.0215***	-0.0290***	-0.0111***
	(0.00723)	(0.00550)	(0.00266)
ln(Lot Size)	0.122***	0.131***	0.122***
	(0.00403)	(0.00226)	(0.00201)
ln(Structure Size)	0.633***	0.654***	0.645***
	(0.00558)	(0.00552)	(0.00221)
Theft per Property	-0.0437	-0.0161	-0.0139***
in Neighbourhood	(0.0360)	(0.0107)	(0.00466)
N	66,624	68,248	261,476
(25th)	0.6255	0.6297	0.5851
Pseudo R^2's (50th)	0.5889	0.5889	0.5606
(75th)	0.5818	0.5822	0.5613

Bootstrapped standard errors in parentheses (20 repetitions)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Treatment·Time represents the added effect of homes that were within 1 kilometre of a Valley Line station under construction. Theft per property in neighbourhood is the total number of robberies, breaking and enterings, and thefts of/from vehicles in a neighbourhood for a given year, divided by the number of properties in that neighbourhood and year. Additional controls included (but not reported) include a garage indicator, year built, distance to the central business district, distance to open LRT stations, and distance to planned Valley Line West stations. The full sample model also contains a trend term.

Table 3: Quantile Difference in Difference Results: Metro Line Extension Opening

	2014 and 2016 (1)	2014 and 2017 (2)	2012-2019 (3)
25th Percentile:			
Treatment·Time	0.00582	-0.00373	-0.0188***
	(0.00726)	(0.0131)	(0.00351)
Apartment	-0.0963***	-0.0962***	-0.121***
	(0.0135)	(0.00817)	(0.00338)
ln(Lot Size)	0.125***	0.139***	0.117***
	(0.00819)	(0.00894)	(0.00545)
ln(Structure Size)	0.721***	0.747***	0.744***
	(0.0134)	(0.0138)	(0.00778)
Theft per Property in Neighbourhood	-0.429***	-0.448***	-0.494***
	(0.0636)	(0.0512)	(0.0407)
50th Percentile:			
Treatment·Time	0.00401	0.0443***	0.0362***
	(0.00715)	(0.00905)	(0.00451)
Apartment	-0.110***	-0.117***	-0.113***
	(0.0143)	(0.0109)	(0.00492)
ln(Lot Size)	0.136***	0.135***	0.123***
	(0.00558)	(0.00743)	(0.00408)
ln(Structure Size)	0.695***	0.733***	0.742***
	(0.0114)	(0.0135)	(0.00519)
Theft per Property in Neighbourhood	-0.427***	-0.499***	-0.472***
	(0.0694)	(0.0810)	(0.0521)
75th Percentile:			
Treatment·Time	0.000522	0.0905***	0.0665***
	(0.0142)	(0.0140)	(0.00697)
Apartment	0.0277	0.0453**	0.000414
	(0.0244)	(0.0217)	(0.00734)
ln(Lot Size)	0.151***	0.138***	0.138***
	(0.00904)	(0.00951)	(0.00558)
ln(Structure Size)	0.809***	0.835***	0.855***
	(0.0176)	(0.0177)	(0.00700)
Theft per Property in Neighbourhood	-0.499**	-0.500***	-0.486***
	(0.254)	(0.155)	(0.117)
N	12,748	12,466	50,165
Pseudo R^2's (25th)	0.6881	0.6821	0.6719
Pseudo R^2's (50th)	0.6235	0.6044	0.6044
Pseudo R^2's (75th)	0.5695	0.5594	0.5663

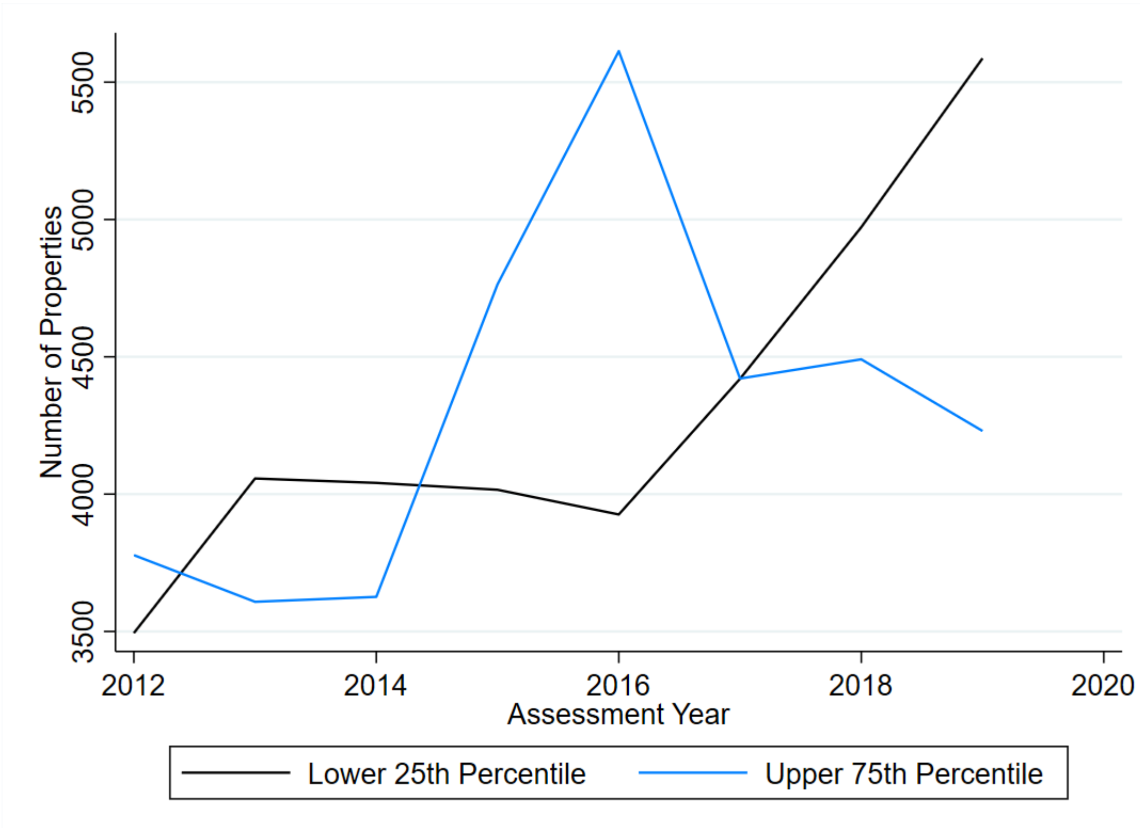
Bootstrapped standard errors in parentheses (20 repetitions)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Treatment·Time represents the added effect of homes that were within 1 kilometre of a Metro Line extension opening. Theft per property in neighbourhood is the total number of robberies, breaking and enterings, and thefts of/from vehicles in a neighbourhood for a given year, divided by the number of properties in that neighbourhood and year. Additional controls included (but not reported) include a garage indicator, year built, distance to the central business district, distance to Rogers place, and distance to a Valley Line SE station. The full sample model also contains a trend term.

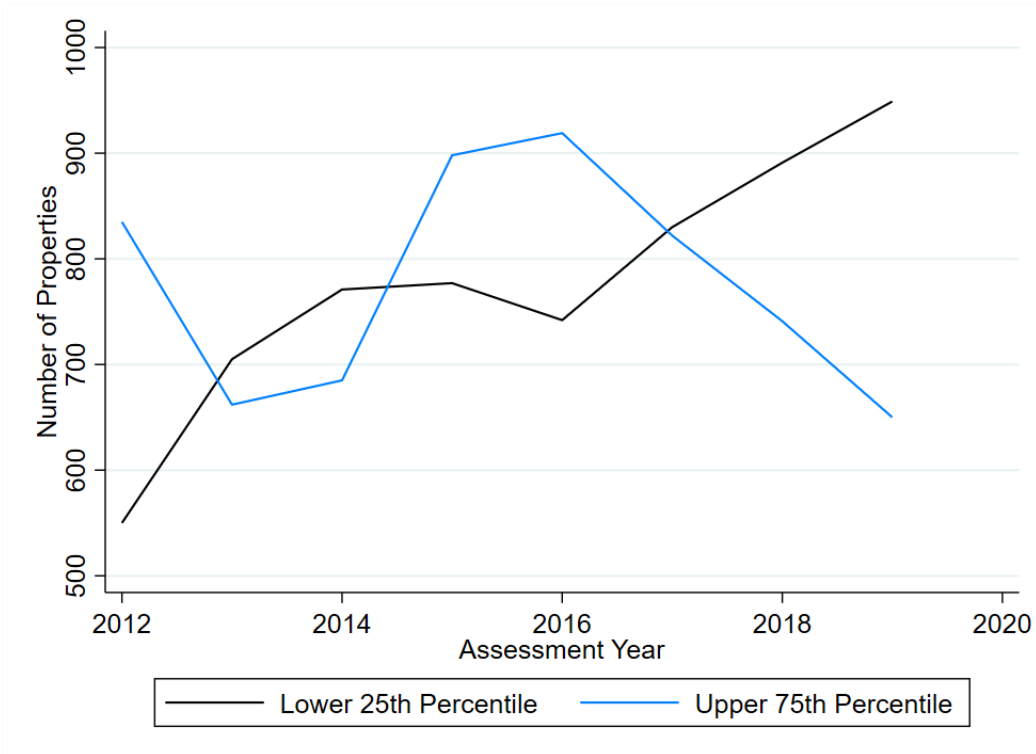
10 Figures

Figure 1: Number of Properties in Treatment Group by Price Percentile and Assessment Year: Valley Line SE Construction



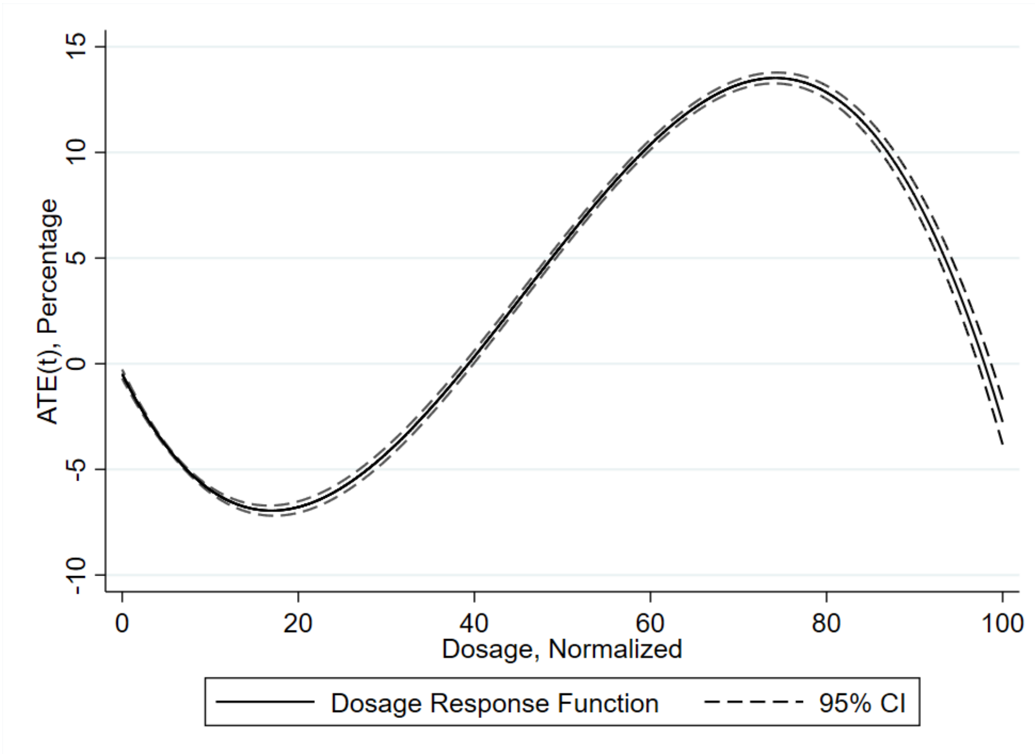
Note: The treatment group are homes within 1 kilometre of the constructed Valley Line SE stations. Percentiles are determined from the full treatment sample (2012-2019) real prices. The lower 25th percentile are homes $164,921.5 and below, and upper 75th percentile are homes $283,844.4 and above (both in 2002 Canadian Dollars).

Figure 2: Number of Properties in Treatment Group by Price Percentile and Assessment Year: Metro Line Expansion



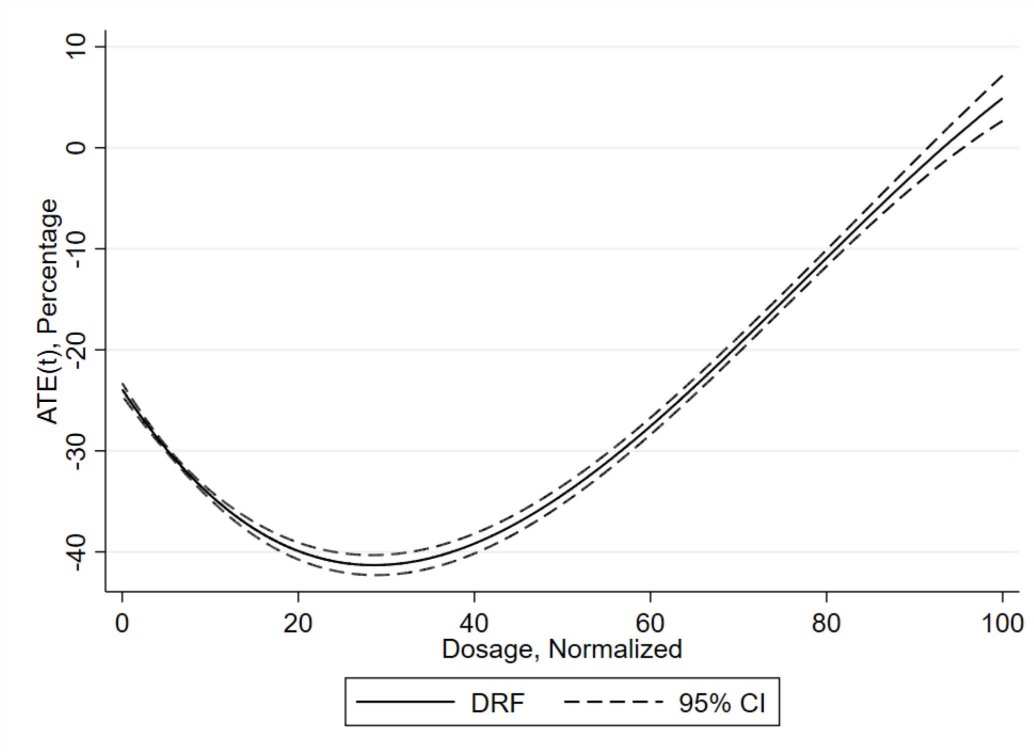
Note: The treatment group are homes within 1 kilometre of the opened Metro Line stations. Percentiles are determined from the full treatment sample (2012-2019) real prices. The lower 25th percentile are homes \$97,606.59 and below, and the upper 75th percentile are homes \$215,960.7 and above (both in 2002 Canadian Dollars).

Figure 3: Dosage Response Functions of Property Prices on Distance to Valley Line SE Construction



Note: Confidence intervals are obtained by bootstrapped standard errors. The Dosage response function maps out the average treatment effect (in percentage) on the treatment group (properties within 1 kilometre of a Valley Line LRT station), as the dosage (distance to the station) varies. Dosages are normalized such that 0 represents the furthest home away in the treatment group (approximately 1 kilometre), and 100 represents the nearest home (approximately 15 metres). Controls utilized include log transformed lot and structure sizes, annual theft rate, apartment and garage indicators, year built, distances to the central business district, open LRT stations, and Valley Line West stations, as well as the assessment year and an indicator for the periods after treatment occurred.

Figure 4: Dosage Response Functions of Property Prices on Distance to Metro Line Opening



Note: Confidence intervals are obtained by bootstrapped standard errors. The Dosage response function maps out the average treatment effect (in percentage) on the treatment group (properties within 1 kilometre of a Metro Line extension station), as the dosage (distance to the station) varies. Dosages are normalized such that 0 represents the furthest home away in the treatment group (approximately 1 kilometre), and 100 represents the nearest home (approximately 17 metres). Controls utilized include log transformed lot and structure size, annual theft rate, apartment and garage indicators, year built, distances to the central business district, and Valley Line SE and West. As well, the assessment year is included and an indicator for the periods after treatment occurred.