Testing

Elizabeth Goodwin

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Contents

1 Introduction

On March 23, 2020, the West Seattle High-Rise Bridge was suddenly closed to all traffic, and is still closed to this day. This bridge, being the most used bridge in all of Seattle, was the primary connection between West Seattle and the rest of the city. This lead to extreme levels of congestion and commute times, with all of the city's traffic being diverted into other bridges connecting West Seattle to the rest of the city. The goal of this paper is to use this exogenous shock to commute times and congestion to measure it's effect on housing prices.

2 Theory

This paper will analyze two main data sources: real-estate prices and average rent. These two measures, while both being housing, operate on very different principles. House prices are a stock, and rent is a flow. This has tremendous impacts for how these measures should be interpreted, as prices are forward looking. Impacts and changes in the prices of housing do not just take in the current circumstances, but are valuated by expected future returns of the asset. All publicly available information should theoretically be reflected in the price of said asset. If market participants expected an extended bridge closure, this may have already been internalized in the price beforehand, and should only change in response to changes in the *expectations*. In addition, as the net present value of a property is determined by (discounted) expected future earnings, if the change in traffic is expected to be short lived, it is unlikely to have a very large effect. While the value of living in said location in the short term may be down, that represents a relatively small amount of the overall future earnings. While real estate is a far less liquid asset than something like equity markets, and is far less standardized (each house is different, but each security is identical), that does not change their forward looking nature.

Rental values, on the other hand, operate very differently. While to some extent they must be forward looking, as prices are typically locked in for the duration of a lease, it is limited in scope. Considering the fact that the bridge was to be closed until at least 2022, this should account for the duration of the vast majority of leases. As a flow variable, rent only represents the current equilibrium price people are willing to pay for housing given the supply of it. If the conditions of the housing (say, commute times) are impacted, this should be priced in regardless of expectations.

In addition, it is logistically much easier to move between locations if you are renting. This could lead to more people who value commute times highly to move locations to other parts of the city, bidding down the relative rent of West Seattle.

In terms of what is being priced in in the first place, differences in the private costs of transportation between various locations should be reflected in the house price. I will explore some of the research behind this in the Literature Review Section, but this paper works off of the hypothesis that there is a significant private cost brought upon by increased congestion/travel times that should theoretically be internalized in the costs of housing.

3 Literature Review

While research on the relationship between commute time and property values is limited, there is research to draw from. Much of the earliest research on this topic comes from using econometric modeling to quantify the costs of congestion. More accurately they are trying to measure the shadow prices of travel time, or the implicit monetary value we all put on travel time. While it may not seem like it at first, this is not all that different from the purpose of this paper. The shadow prices consumers put on travel time should reflect themselves in the premium they pay for living closer to their workplace.

The seminal paper on these models is by Vickrey (1969). It models equilibrium congestion of a fixed bottleneck (major roadway, can only have so much traffic at a time) in response to commuters decisions on when they will leave for work. Equilibrium is reached when the private costs of either arriving too early or too late equals the private cost of the current commute time, making the total private commute cost not vary over time. In other words, it is when, on average, people value being x minutes late/early the same amount as they value the drop in commute times achieved by leaving for work later/earlier.

This model was expanded on in Arnott, de Palma, and Lindsey (1993) using a structural approach to dynamically model road congestion with elastic trip demand. This allows for the congestion itself to respond to the decisions of drivers to take the trip in the first place, as changes in the private cost of the trip (shadow price of increased commute, price of being late, etc) will change peoples willingness to drive in the first place depending on the elasticity of their demand curve. The private cost of the trip should vary quite a lot between drivers, with people with inelastic demand curves (commuters) likely to drive even with congestion, and therefore make up a higher concentration of the drivers during congested times. The model supports this conclusion, and explains the composition of drivers in rush hour traffic. It also has implications for this paper as well, as a sudden exogenous shock restricting the size of the bottleneck may cause this effect to be magnified significantly. Drivers with inelastic demand are likely to make up an even greater share of the remaining roadways, and others planning if or how they travel around this shock in congestion.

Before these models can be tied into land use, I must first introduce the Monocentric City Model developed by Alonso (1964), Muth (1969), and Mills (1967) and formalized by W. C. Wheaton (1974). This is one of the most influential models in urban economics, and models the spatial structures of cities. It's spatial equilibrium condition has the utility of all residents living any distance from the central business district (CBD) to be the same. Results of this condition has the price of housing decrease with distance from the CBD, housing consumption increase with distance from CBD (meaning size of home, etc), and density decreasing with distance from CBD.

$$\max_{q} = v(y - \tau x - p(x)q(x), q) = u$$

The commuting cost of the model is a linear function of the distance from the CBD, τx, with x being the distance from the CBD. Consumers have utility $v(z, q)$ over numeraire z and housing q. All residents have equilibrium utility u and income y. While this model is very useful, and predicts increased travel time reducing housing values, it weights it as a simple linear function of distance. However, heterogeneous transportation costs can easily be incorporated into the model by changing the function $\tau(x)$. Wheaton (1998) does something similar, and incorporates congestion as a market externality into the model. This results in the optimal density of housing being several times higher than market cities.

Fosgerau, Kim, and Ranjan (2018) combines the Vickrey (1969) bottleneck congestion model with the Alonso (1964) monocentric city model. In the model, residents maximize their commute departure time along with the other variables in $\max v(z, q)$ and arrive at the bottleneck in order of distance from CBD. It finds the opposite of earlier research, with a socially optimal toll causing residents to commute earlier than they would otherwise, creating a less dense city. Fosgerau and Kim (2019) expands on this by adding more business districts, along with suburban residential zones. These locations are connected by two separate bridges that are subject to Vickrey (1969)'s bottleneck congestion. This also allows for spatial differences in how residents are exposed to congestion in the first place, as suburban commuters have to face a different number of bottlenecks. This is very interesting in how it applies to this paper, as West Seattle is very similar to this. Transport time is not just a factor of distance from the CBD, but also constrained by a number of potential bottlenecks.

These models show themselves in the real world as well. Blake (2019), also using Zillow data, observed a relation between home values and transportation using variations in the price of gas. He found a large effect, with every $1 increase in the price of gas decreasing housing values by 0.143% for every additional mile of commute. That came to an average of $5200 for the average commute, and interestingly translated to a discount rate similar to mortgages at the time. Zhang and Burke (2022) performed a similar analysis using data from Chinese cities, finding a 1% increase in gas prices causing a 0.004% reduction is home prices per km from CBD. The effect was larger in cities with more automotive use and less dense areas.

In Agarwal, Koo, and Sing (2015), a exogenous shock in the Electronic Road Pricing (ERP) system in Singapore was used to test the effects of congestion pricing on real estate pricing. The ERP system is a network of toll systems that tax vehicles entering the city center, and the pricing structure of said system had a sudden increase in November 2010. They used a diff-in-diff methodology to estimate the change and found a 19% drop in retail property values within the area the ERP effected, but no significant changes in private office or residential real estate. This has interesting implications for this paper as well, as both are exogenous shocks to transport costs / times. There is a difference in what it is measuring, however, as housing already within the city center is far less likely to have people regularly commuting either by car, or to somewhere of significant distance, as they are already in the city center. Still has interesting implications, however.

The final paper I analyzed was Delventhal, Kwon, and Parkhomenko (2022), which analyzes how the shift to work from home commuting effects the shape of cities. I find this relevant given the timing of the closure of the West Seattle bridge leads to this shift possibly complicating the effects measured. It finds that a shift to work from home makes jobs move closer to the city center, and residents move further from the center. It also finds that real estate prices fall on average, with declines in core locations and increases in peripheral locations. This complicates the story somewhat, as these changes could disrupt previous pricing trends, and counteract some of the possible negative effects from the bridge closure in the first place.

4 Data

4.1 Data Source

The primary data source for this project is from Zillow. The housing data is from their Zillow Home Value Index (Zillow Group, Inc. 2022a), which is the estimated value of the 'typical' home within the given region. The format used by this project is separated by zip code, as that is the format that allows for the best division of Seattle out of all the available formats. The dataset starts from January 1st, 2000 and ends on March of 2022. The secondary dataset used by this project is the Zillow Observed Rent Index (Zillow Group, Inc. 2022b), also separated by zipcode. Unfortunately, this dataset is far more limited in scope, only starting in 2014 and with several areas of missing data depending on the zipcode. Both of these datasets are limited by how they are aggregated. While zipcodes can be used to separate West Seattle from the rest of the city, they are still quite arbitrary. In addition, they represent different populations and may have fundamentally different compositions of housing.

4.2 Overview

The Zillow datasets are separated by zipcodes, which makes things somewhat complicated.In Figure 1, the zipcodes of all of seattle are displayed. Without any better alternative, what I did was to bucketize the zipcodes into those in and outside of West Seattle. The zip codes of Seattle listed in Table 1, with their bucket listed. After that, I created a weighted average of each bucket over time, weighting by overall population. In Figure 2 I plotted the two buckets over time. In Figure 3 I plotted the same data, but took the natural log of the price over time. This is important, as logs measure rate of change, and that is what is important for this analysis.

Table 1: Zip Codes of Seattle and location

zip	population	location
98106	27997	West Seattle
98116	28705	West Seattle
98126	22681	West Seattle
98136	17083	West Seattle
98101	14380	Rest of Seattle
98102	25887	Rest of Seattle
98103	54194	Rest of Seattle
98104	15155	Rest of Seattle
98105	52290	Rest of Seattle
98107	28025	Rest of Seattle
98108	24034	Rest of Seattle
98109	31011	Rest of Seattle
98112	25694	Rest of Seattle
98115	55519	Rest of Seattle
98117	36647	Rest of Seattle
98118	49702	Rest of Seattle
98119	26898	Rest of Seattle
98121	20534	Rest of Seattle
98122	41152	Rest of Seattle
98125	44030	Rest of Seattle
98133	49476	Rest of Seattle
98144	33175	Rest of Seattle
98146	27622	Rest of Seattle
98148	11514	Rest of Seattle
98155	35420	Rest of Seattle
98166	21772	Rest of Seattle
98168	33217	Rest of Seattle
98177	20422	Rest of Seattle
98178	26507	Rest of Seattle
98188	25292	Rest of Seattle
98195	51	Rest of Seattle
98198	38699	Rest of Seattle
98199	23444	Rest of Seattle

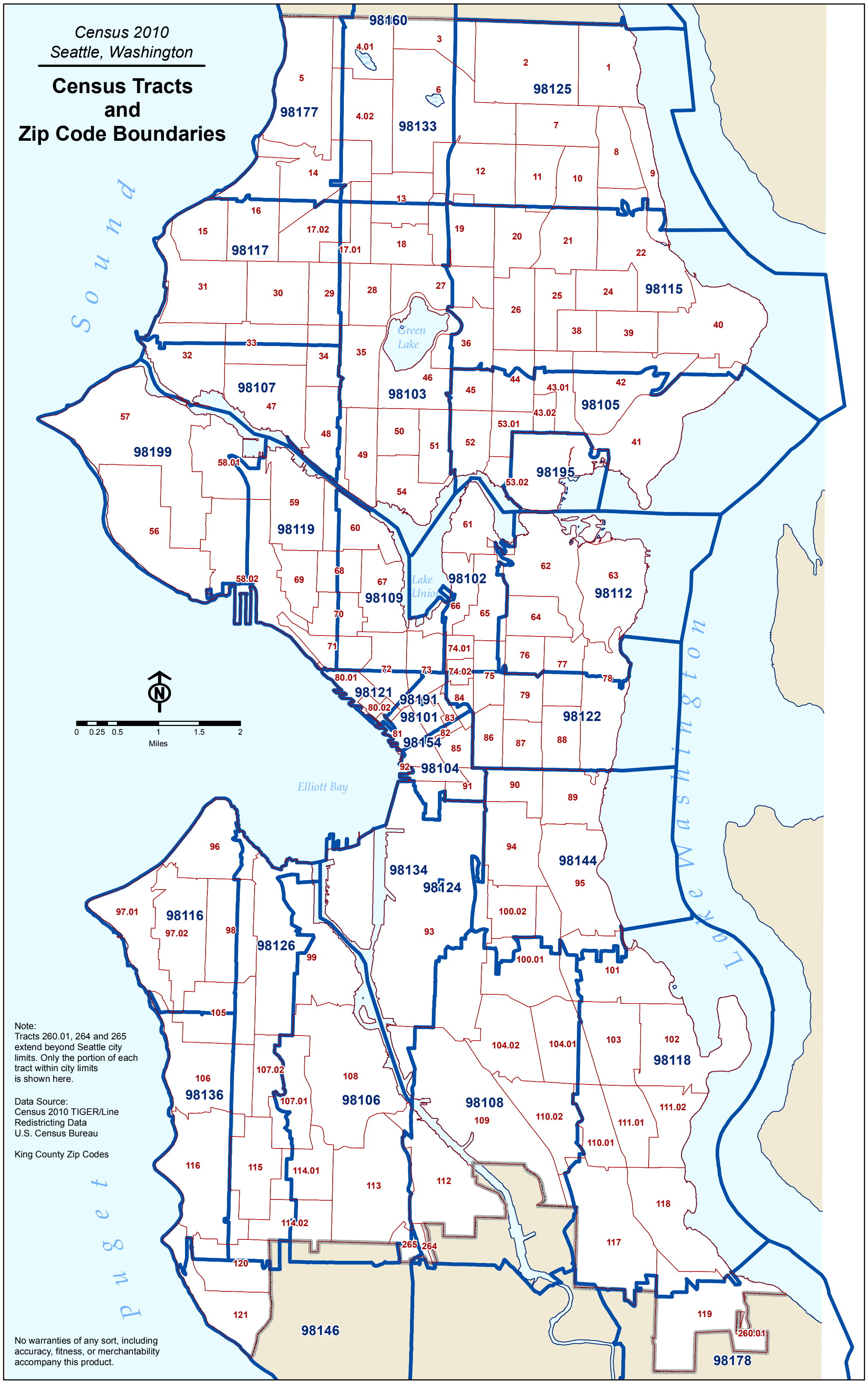

Figure 1: Map of Seattle Zip Codes (Seattle OPCD 2010)

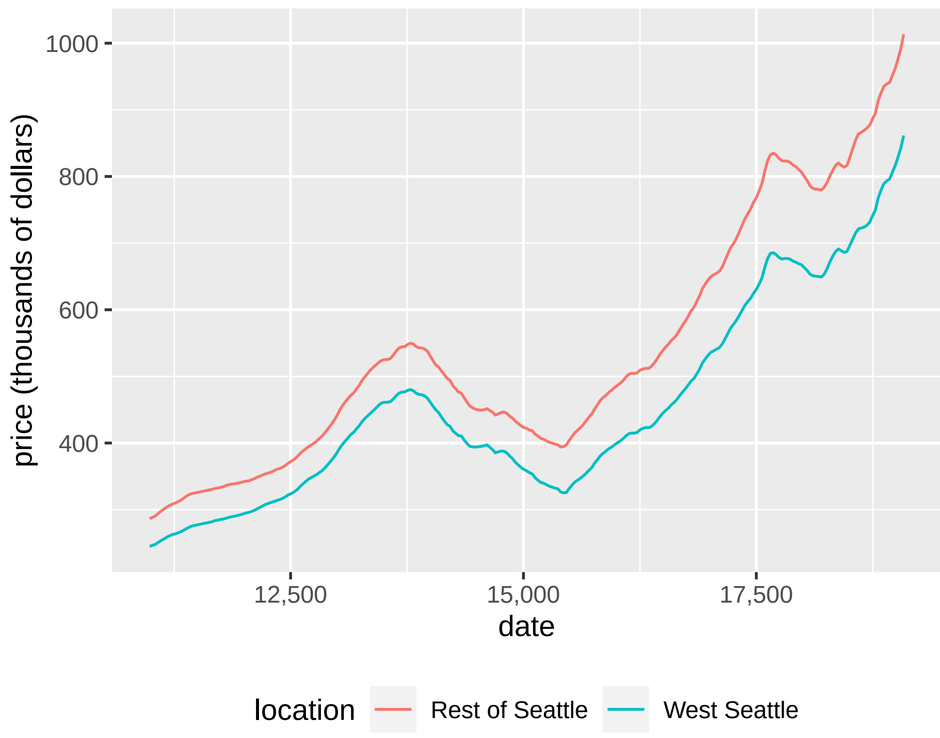

Figure 2: Prices of West and rest of Seattle Compared

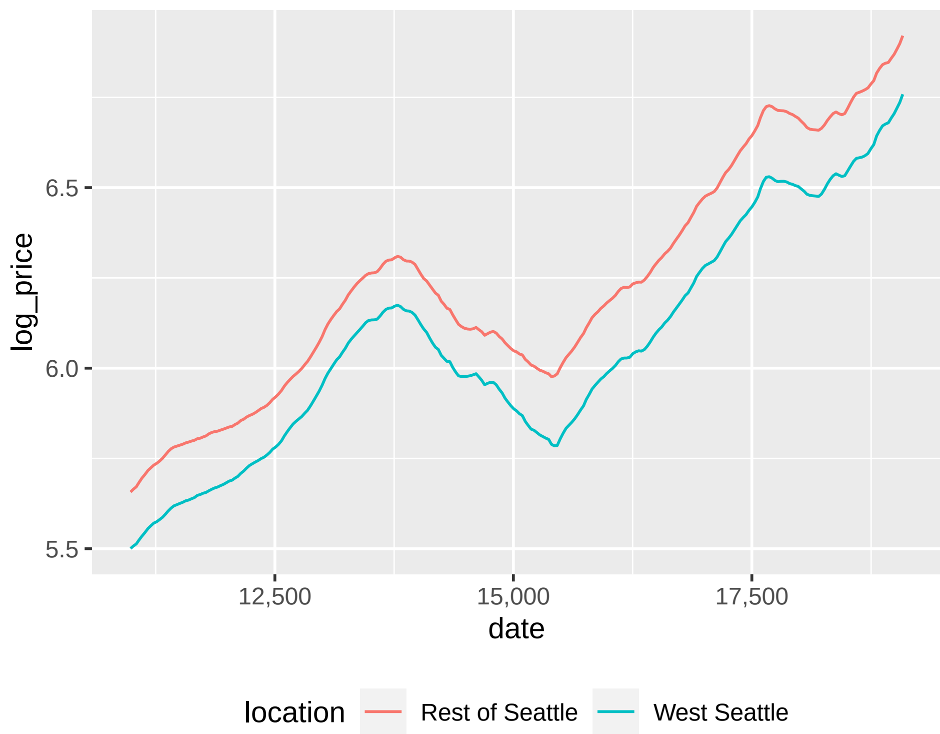

Figure 3: Prices of West and rest of Seattle Compared (logged)

4.3 Limitations

For any of the results of this paper to be causally significant, the effect measured must represent the exogenous impact of the closure of the West Seattle bridge. For several reasons, this is exceptionally difficult. The first and most important of these assumptions is the parallel trends assumption. For a differences in differences approach, we must assume that absent the treatment (ie, closure of the West Seattle Bridge), the trend of the treated group would match that of the control group. In this case, this means the price trend of the rest of Seattle that did not rely on said bridge represents what would have happened to the prices in West Seattle if the closure had never occurred. This assumption is frankly very hard to justify for multiple reasons. The first and most obvious of which is the fact that the closure of the West Seattle bridge unfortunately occurred in the midst of the beginning of the COVID-19 pandemic. The results of the pandemic could have easily effected different parts of the city in fundamentally different ways, with housing values being no exception. While intending to measure the exogenous impact of the bridge closure, we could actually be measuring the effects of the pandemic effecting certain parts of the city over others due to some missing variable. It could also go in the other direction, hiding any exogenous impact of the closure or lessening the impact of commutes due to a pandemic lockdown pushing many to no longer have to commute in the first place. Essentially, having such a large exogenous shock to the economy coinciding with the shutdown makes it very difficult to measure.

In addition, it is difficult to know which zip codes were effected the largest. To do this, we would have to basket or select certain zip codes into control and treatment groups, but the shutdown of an important bridge in a large city is likely to have effects on large areas of the city. This concern, while very real, does seem likely to only dampen the effects of the closure, not exaggerate them, as it would just mean one area of the city experienced the fallout of the closure harder than the rest, as no section seems likely to outright benefit from the closure. The parallel trends assumption will be difficult to measure, though. For something with as much variance as real estate prices, the prices of any two zip codes are unlikely to very closely match. While they could easily be correlated, it could easily require a very large difference to represent any statistically significant change.

The first part of this process

Table 2: Means of pre and post treatment. Defined Febuary as pre and April as post.

location	date	price	datemonth	treated	log_price	idname	time
Rest of Seattle	2020-02-29	809209.4	2	0	13.60381	1	0
Rest of Seattle	2020-03-31	816771.8	3	0	13.61312	1	1
West Seattle	2020-02-29	680540.9	2	0	13.43064	0	0
West Seattle	2020-03-31	687494.4	3	1	13.44081	0	1

	Model 1
time	0.01^{***}
	(0.00)
treated	0.00^{***}
	(0.00)

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 3: Statistical models

5 Model

As mentioned earlier, this paper will be using a Two way fixed effect differences in differences model. The fundamental assumption of this model is the parallel trends assumption. As seen in Figures 2 and 3, at least visually, the parallel trends assumption appears to be relatively accurate. Although, only really the logged graph appears that way.

```
##
## z test of coefficients:
##
##           Estimate Std. Error z value              Pr(>|z|)
## time    0.00930196 0.00000000     Inf < 0.00000000000000022 ***
## treated 0.00086375 0.00000000     Inf < 0.00000000000000022 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

6 Results

7 Analysis

8 Conclusion

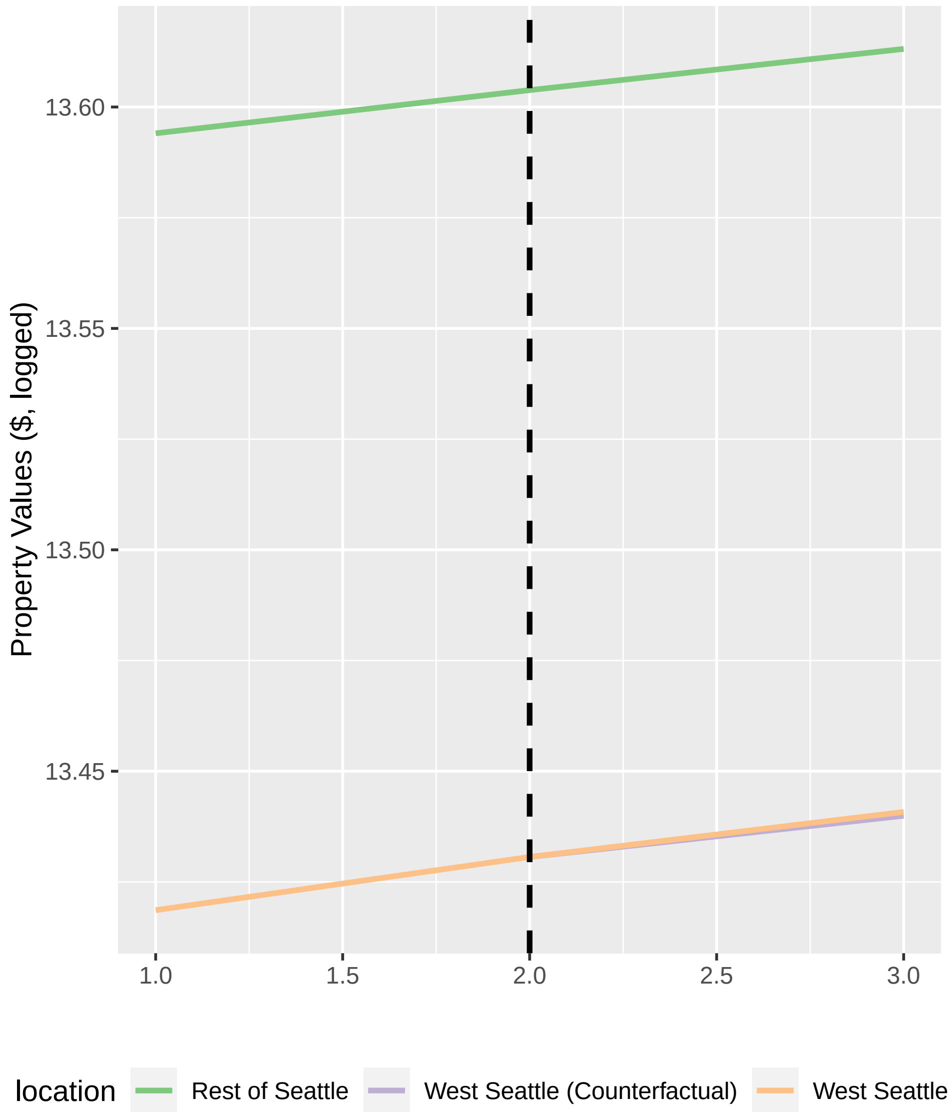

Figure 4: Graphical representation of model

```
## Warning: Removed 3 row(s) containing missing values (geom_path).
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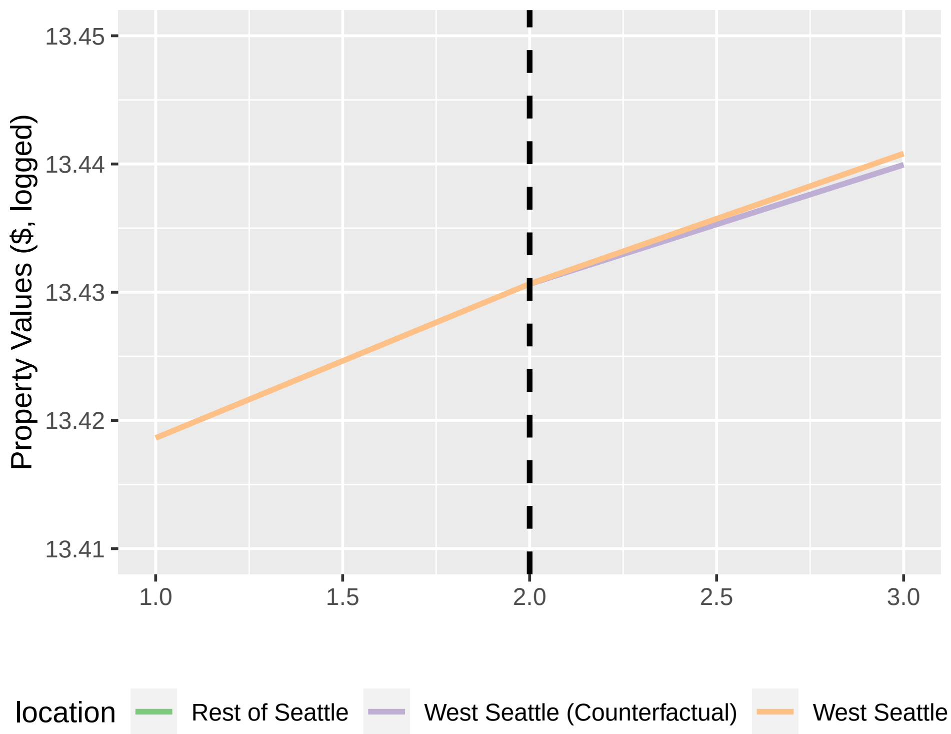

Figure 5: Graphical representation of model (zoomed in)

Bibliography

Agarwal, Sumit, Kang Mo Koo, and Tien Foo Sing. 2015. "Impact of Electronic Road Pricing on Real Estate Prices in Singapore." *Journal of Urban Economics* 90 (November): 50–59. https://doi.org/10.1016/j.jue.2015.09.004.

Alonso, William. 1964. *Location and Land Use: Toward a General Theory of Land Rent*. *Location and Land Use*. Harvard University Press. https://doi.org/10.4159/harvard.9780674730854.

Arnott, Richard, André de Palma, and Robin Lindsey. 1993. "A Structural Model of Peak-Period Congestion: A Traffic Bottleneck with Elastic Demand." *The American Economic Review* 83 (1): 161–79. https://www.jstor.org/stable/2117502.

Blake, Thomas. 2019. "Commuting Costs and Geographic Sorting in the Housing Market." *Real Estate Economics* 47 (4): 1089–1118. https://doi.org/10.1111/1540-6229.12159.

Delventhal, Matthew J., Eunjee Kwon, and Andrii Parkhomenko. 2022. "JUE Insight: How Do Cities Change When We Work from Home?" *Journal of Urban Economics*, JUE Insights: COVID-19 and Cities, 127 (January): 103331. https://doi.org/10.1016/j.jue.2021.103331.

Fosgerau, Mogens, and Jinwon Kim. 2019. "Commuting and Land Use in a City with Bottlenecks: Theory and Evidence." *Regional Science and Urban Economics* 77 (July): 182–204. https://doi.org/10.1016/j.regsciurbeco.2019.04.004.

Fosgerau, Mogens, Jinwon Kim, and Abhishek Ranjan. 2018. "Vickrey Meets Alonso: Commute Scheduling and Congestion in a Monocentric City." *Journal of Urban Economics* 105 (May): 40–53. https://doi.org/10.1016/j.jue.2018.02.003.

Gaure, Simen. 2013. "lfe: Linear Group Fixed Effects." *The R Journal* 5 (2): 104–17. https://journal.r-project.org/archive/2013/RJ-2013-031/RJ-2013-031.pdf.

———. 2022. *Lfe: Linear Group Fixed Effects*. Manual. https://github.com/MatthieuStigler/lfe.

Mills, Edwin S. 1967. "An Aggregative Model of Resource Allocation in a Metropolitan Area." *The American Economic Review* 57 (2): 197–210. https://www.jstor.org/stable/1821621.

Muth, Richard F. 1969. "CITIES AND HOUSING; THE SPATIAL PATTERN OF URBAN RESIDENTIAL LAND USE."

Seattle OPCD. 2010. "Seattle 2010 Census Tracts and Zip Code Areas Map." 2010. https://www.seattle.gov/opcd/population-and-demographics/geographic-files-and-maps#2010census.

Vickrey, William S. 1969. "Congestion Theory and Transport Investment." *The American Economic Review* 59 (2): 251–60. https://www.jstor.org/stable/1823678.

Wheaton. 1998. "Land Use and Density in Cities with Congestion." *Journal of Urban Economics* 43 (2): 258–72. https://doi.org/10.1006/juec.1997.2043.

Wheaton, William C. 1974. "A Comparative Static Analysis of Urban Spatial Structure." *Journal of Economic Theory* 9 (2): 223–37. https://doi.org/10.1016/0022-0531(74)90068-4.

Zhang, Tong, and Paul J. Burke. 2022. "The Effect of Gasoline Prices on Suburban Housing Values in China." *China Economic Review* 72 (April): 101762. https://doi.org/10.1016/j.chieco.2022.101762.

Zillow Group, Inc. 2022a. "Zillow Home Value Index (ZHVI)." https://www.zillow.com/research/data/.

———. 2022b. "Zillow Observed Rent Index (ZORI)." https://www.zillow.com/research/data/.