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THE ECONOMIC IMPACT OF THE SEATTLE AREA'S TRANSPORTATION INFRASTRUCTURE EXPANSIONS AND CHANGES

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THE ECONOMIC IMPACT OF THE SEATTLE AREA'S TRANSPORTATION INFRASTRUCTURE EXPANSIONS AND CHANGES

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Business and Economics at the University of Kentucky

By

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2017

ABSTRACT OF DISSERTATION

THE ECONOMIC IMPACT OF THE SEATTLE AREA'S TRANSPORTATION INFRASTRUCTURE EXPANSIONS AND CHANGES

This paper uses annual, tract-level data to estimate the economic impact of the Seattle area's newly operational light rail system and recently implemented toll on a bridge traversing Lake Washington, the large lake immediately east of Seattle that bisects the region. Two modeling approaches are utilized in the estimation of each transit intervention's economic impact: the primary model allows the transit intervention to affect the designated impact area prior to the system's operation, under the assumption that individuals will respond to the knowledge of the change and relocate accordingly. The secondary model accounts for an impact from the intervention upon its operation. Zoning designations are incorporated into the measurement of a tract's proximity to the transit interventions to control for the possibility of the expansion of a residential or commercial presence. The economic impact from the light rail and toll are modeled both individually and in a combined model.

The impact of the light rail is measured within a ¼ mile of stations. Two station types are controlled for within the estimation of the light rail system's economic impact: retrofit stations previously existed as bus stations that were fit with light rail infrastructure, while new stations were built specifically for the light rail. Both station types are associated with increases in population density and housing density, and decreases in employment density, while the prevalence of public sector employment has decreased around new stations. The two station types differently attract residents based on age. A majority of the increases in population and housing density surrounding stations occurred prior to the system's operation, whereas a majority of the decrease in employment density surrounding stations occurred during the system's first year of operation.

Narrow and broad definitions of bridge proximity are utilized in estimating the toll's impact. The toll is associated with small increases in population density and employment density using both definitions of bridge proximity. Within the narrow definition of bridge proximity, a majority of the increase in population density occurred prior to the toll's operation, whereas a majority of the increase in employment density occurred during the toll's first year of operation. Within the broad definition of bridge proximity, a majority of the increases in population and employment density occurred once the toll was operational. Neither transit intervention has affected the prevalence of African Americans within the designated transit impact areas.

KEYORDS: Economic Impact, Infrastructure, Light Rail, Toll, Urban Form

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September 8, 2019

Date

THE ECONOMIC IMPACT OF THE SEATTLE AREA’S TRANSPORTATION INFRASTRUCTURE EXPANSIONS AND CHANGES

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. Introduction

Policy makers and governmental officials have incentives to limit heavy congestion. Heavy congestion results in lost economic productivity, environmental degradation and tightened city budgets as more funds are allocated to the maintenance and construction of the necessary infrastructure to access distant suburbs (Texas Transportation Institute, 2011). Excessive use beyond a corridor's intended capacity drastically accelerates its deterioration, increasing the frequency with which it will need repairs and ultimately decreasing its working lifetime. Given the stressed states of many government budgets, allocating resources to repairs due to excessive usage is often seen as an expense that could be circumvented if appropriate measures were taken.

Beyond the explicit costs induced by increased wear and tear on highways, are the indirect costs associated with increases in travel time. Increases in travel time result in lost economic productivity for an individual because of fewer hours at work and a diminished quality of life because of fewer hours enjoying the community with family. Another dire implicit cost is the heightened emissions resulting from the increase in fuel consumption. Both factors post staggering numbers in the aggregate within the United States: in 2014, 6.9 billion hours were spent idling due to congestion, and 3.1 billion gallons of additional fuel were consumed due to additional travel hours (Texas Transportation Institute, 2015).

One region that has struggled with congestion during the last several decades is central Puget Sound, the area of northwestern Washington centered on the city of Seattle. Seattle has not always been known for its terrible traffic. In 1982, the average citizen of Seattle spent 10 hours a year stuck in traffic, putting Seattle at the bottom of congestion rankings for large urban areas (Texas Transportation Institute, 2011). However, as the region's population grew, Seattle's congestion worsened: in 2014, Seattle was ranked as having the 6th worst congestion in the country, with the average citizen spending 63 hours a year idling in traffic (Texas Transportation Institute, 2015).

Figure 1 - Map of the Seattle Region

The unique geography of the region imposes severe limits on the area available to build or expand freeways as the population grows. Seattle is located on a narrow strip of land bordered on the west by the Puget Sound – an inlet of the Pacific Ocean- and on the east by Lake Washington – a twenty-one-mile freshwater lake (see Figure 1). These geographic constraints funnel drivers into a set route with few substitutes (Texas Transportation Institute, 2011).

One approach to move a greater number of people in this dense and highly congested area is to create incentives to use public transit and to discourage the use of personal vehicles. To induce individuals to substitute away from a personal vehicle, public transit must be inexpensive, fast, reliable and easily accessible (Beirão and Cabral, 2007). In the early 1990's, policy makers in the greater Seattle area began planning the region's first light rail system to link downtown Seattle to the region's main airport and to provide light rail service through the city of Tacoma. These plans were finalized in 1996 and approved by voters. Construction on the first light rail stations began in 2002, and the system began operating in July of 2009 along a 15.4-mile route. Two stations and three miles of track were added in 2016. Recently passed ballot initiatives will further extend the system throughout the region. *Section II* provides an expanded discussion of the region's transit initiatives.

Expansions of public transit access could increase population and employment density around stations if access to these services is valued. Households and firms may place differing degrees of value on public transit proximity, and new residential and commercial hubs could be created. There also may be variation in the demographic response to the expansion of public transportation services, resulting in not only new high density areas but changes in the distribution of demographics across a region.

Another means of reducing congestion is by increasing the opportunity cost of driving a personal vehicle. The implementation of tolls on certain highway segments could encourage drivers to switch to public transit, drive during off-peak hours, or carpool, potentially leading to a decrease in the total volume of traffic on a given corridor and smoothing traffic volumes over a 24-hour period. In an aim to alleviate congestion and to raise funds for infrastructure improvements, the Washington State Transportation Commission (WSTC)—the tolling authority in the state-- increased the marginal cost of driving on several freeway segments throughout the region. Two bridges traverse Lake Washington: the Evergreen Point Floating Bridge (SR-520) to the north and the I-90 to the south (see Figure 1). In December of 2011, the WSTC began charging a toll on the SR-520, creating a natural experiment in which to evaluate the impact of the toll.

According to the Tiebout hypothesis (1956), households will locate where the level of taxation and public goods provided best coincides with their personal preferences. The implementation of a toll on a highway segment is essentially equivalent to a tax: households and firms that do not value the good provided by the tax (i.e. access) relative to its cost may choose to relocate. On the other hand, individuals with inelastic preferences for the tolled corridor or with very strong inclinations towards the driving of a personal vehicle may relocate towards the tolled corridor to take advantage of the expedited travel resulting from the redistribution of traffic. These changes to highway demand could affect individuals' and firms' locational decisions, potentially leading to shifting in population and employment hubs.

To encourage densification around stations and to provide further incentives to substitute to public transit, the City has implemented policies that require large employers to reduce the percentage of workers commuting alone, restrict parking facilities in residential areas and incentivize developers to build affordable units around stations. Additionally, the adoption of Resolution R2012-24 in December of 2012 requires the regional transit authority (Sound Transit) to be directly involved in the construction of communities around light rail stations. These policies are discussed in further detail in *Section II.C*.

Using a data panel of ten years, this work quantifies the impact from the implementation of the central Puget Sound's light rail system and the SR-520 toll on population, employment and demographics within defined transit impact areas. The analysis of each intervention requires the creation of a unique data set recording the percentage of each study area census tract's spatial relationship with the light rail stations and the two bridges traversing Lake Washington. I incorporate zoning designations into each tract's recorded spatial relationship with the corresponding transit features to control for the possibility of an expanded commercial or residential presence. In the estimation of both transit interventions, I attempt to capture preemptive household and firm relocations in response to the system in question through the usage of weights applied to the terms of interest prior to the activation of the system. I also estimate the impact of each intervention upon their operation. All variables are analyzed at the census tract level.

Both transit interventions appear to be impacting the distribution of population and employment throughout the region. Within the light rail estimation, I control for the preexisting urban form surrounding stations by designating stations as *retrofit* (prior bus stations that were retrofit with light rail infrastructure) or *new* (stations that were built specifically for the light rail system). Both station types are associated with large increases in population density and housing density, while retrofit stations are associated with very large decreases in employment density. The composition of employment surrounding new stations has also adjusted in favor of the private sector. The two station types appeal to individuals of different ages, with the average age decreasing around retrofit stations and increasing around new stations. The light rail does not appeal to individuals differentially based on race. Households anticipated the operation of the light rail, with a vast majority of the resulting increase in population density and housing density surrounding stations occurring prior to the system's operation. Firms were more likely to delay their locational adjustments, with a majority of firm relocations away from the light rail stations occurring during the first full year of the system's operation.

Narrow and broad definitions of bridge proximity are used in the estimation of the toll's economic impact. The narrow definition accounts for an impact from the toll in all tracts with any portion of area within two miles of the SR-520 bridge termini. The broad definition accounts for an impact from the toll in all tracts with any portion of area within 1.5 miles of an entrance or exit ramp within five miles of the SR-520 bridge termini. The toll is associated with small but similar increases in population across both bridge proximity bounds, and is associated with increases in employment within both proximity bounds, although the employment increases are orders of magnitude larger within two miles of the SR-520 bridge termini. The majority of population relocations toward the SR-520 bridge within the two-mile termini boundary occurred prior to the toll's operation, while the majority of population relocations towards freeway ramps within five miles of the bridge termini occurred once the toll was operational. The majority of employment relocations across both proximity definitions occurred once the toll was operational. The toll does not differentially appeal to individuals of different ages and races in either impact area.

The quantification of the extent to which populations and firms migrate in response to increased availability of public transit and increased usage costs in the short run can inform as to what policies may be beneficial in order to achieve the desired long run effect. This analysis serves as a needed addition to the literature in that it provides a contemporary analysis of a light rail system in progress and exploits the natural variation created by the existence of the alternate Lake Washington bridge at a very fine geographical unit. Although the post-implementation time frame for each intervention is not as expansive as may be ideal, the short run impacts quantified in this work could inform local policy makers of needed adjustments that may enable stations in transitory stages to exhibit the idealized impact on the surrounding community and may further inform policy regarding tolling in the region. Furthermore, in the hopes of being able to make the most accurate policy recommendations, this analysis takes into account many degrees of heterogeneity that are often excluded in the literature. These additional controls may influence locational decisions and their inclusion is likely to produce more accurate and informative coefficient estimates.

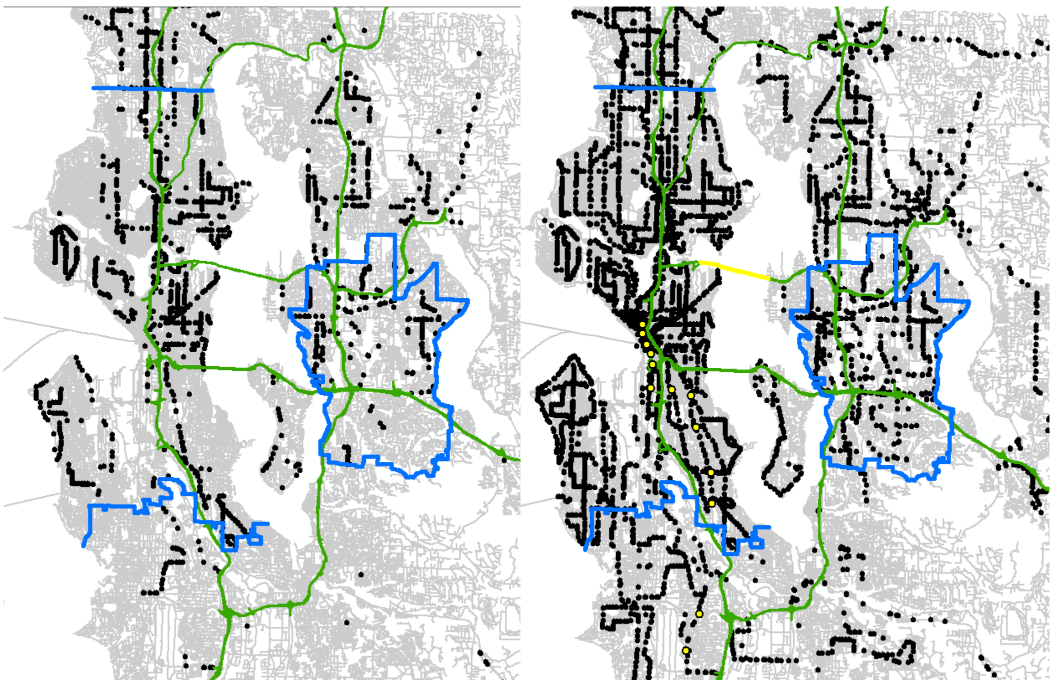
As a note to the reader, when referring to "Seattle," I am referring to the municipal entity that is the City of Seattle, defined by precise boundaries and possessing political and legal authority within said boundaries. When I refer to the "Seattle area," I am referring to the geographical region with vague boundaries centered on the municipal entity that is the City of Seattle. As the package of funding and initiatives enacted to bring these transportation innovations to fruition involves a complex arrangement consisting of funding allocated by city, state and federal monies, this distinction is important throughout the text.

II. The Seattle Area's Transportation Innovations

II.A. Overview

The City of Seattle lies on a narrow peninsula bordered by two bodies of water: the Puget Sound to the West and Lake Washington to the East (see Figure 1). At its narrowest point,

Figure 2 – Pre-and-Post Expansion Transportation Infrastructure



The pre-expansion transportation infrastructure and the transportation infrastructure evaluated within this work are depicted above. The boundaries of Seattle (west) and Bellevue (east) are delineated in blue, major freeways are in green and bus stops are represented by black circles. The panel to the left depicts the pre-expansion system in 1995. The panel to the right indicates the location of the operational light rail stations in 2014 (yellow circles) and the tolled SR-520 bridge (yellow).

Seattle is only three miles wide, yet, in 2014, the municipality of Seattle encompassed 554,710 jobs and 729,768 residents (see Figure 2).[1] The Puget Sound also contains many

[1] Determined using a shapefile from data.seattle.gov of the municipality of Seattle’s boundaries and Puget Sound Regional Council data on employment and population per tract in 2014. Figure 2 delineates the boundaries of Seattle.

residential islands from which workers commute into the city by ferry, contributing to the daily influx of travelers descending onto the City. There is also a highly residential island within Lake Washington traversed by the I-90 bridge, with the majority of the island's commuters using the I-90 bridge to travel off-island for employment.

Another major metropolitan area, Bellevue, lies on the east side of Lake Washington. Major branches of Boeing and Microsoft are situated on the east side of the lake, as are T-Mobile's headquarters. In 2014, there were 187,069 jobs and 190,305 residents in Bellevue (see Figure 2).[2] All traffic moving between Seattle and Bellevue must utilize the two cross-lake bridges or must circumnavigate the twenty-one-mile lake to the North or South.

Dense residential communities and employment centers lie north and south of Seattle as well, although there are no geographic barriers impeding travel in these directions. Three dense residential satellite towns (Shoreline, Lynnwood and Everett) exist within 30 miles of Seattle to the North. Everett also encompasses a major manufacturing center for Boeing, as well as a naval station. Three dense residential centers also lie within 25 miles of Seattle to the South (Renton, Kent and Auburn). Additionally, Tacoma, an industrial port city with the third largest population in Washington, lies 30 miles to the South and Olympia, the capital of Washington state, lies 60 miles to the Southwest (see Figure 1).

Several large interstate systems service the region (see Figure 1): I-5 and I-405 are oriented north to south, with I-5 bisecting the Seattle peninsula from Everett to Tacoma and continuing southwest through Olympia. I-405 runs along the east side of Lake Washington.

[2] Determined using a shapefile from ci.bellevue.wa.us of the municipality of Bellevue's boundaries and Puget Sound Regional Council data on employment and population per tract in 2014. Figure 2 delineates the boundaries of Bellevue.

I-5 and I-405 join north and south of Lake Washington. I-90 and SR-520 are oriented east to west and connect the western portion of the Seattle peninsula to the eastern side of Lake Washington through the two bridges crossing the lake. The SR-520 crosses the lake to the North and connects the University of Washington district on the west side of the lake with Medina, a wealthy residential suburb of Bellevue on the east side of the lake. The I-90 is the southern bridge crossing the lake and intersects with Mercer Island, a wealthy residential community, in Lake Washington.

II.B. The Seattle Area's Light Rail System

King County is "required to prepare, adopt and carry out a general Comprehensive Plan for Public Transportation that will best serve the residents of the Seattle-King County metropolitan area and to amend said plan from time to time to meet changed conditions and requirements." (King County Resolution No. 6641) In 1993, King, Pierce and Snohomish counties voted to create the Regional Transit Authority (RTA) with the intent of the development of a new Comprehensive Plan due to a recognition that the "existing transportation facilities in the central Puget Sound area [were] inadequate to address mobility needs of the area." (King County Resolution No. 6641) The left panel of Figure 2 depicts the major transportation infrastructure that existed in the region in 1995: bus stations are represented by black circles and the major interstates are in green. The right panel in Figure 2 displays the state of the transportation infrastructure system in 2014, the last year of the panel analyzed within this work. Operational light rail stations (as of 2014) and the tolled segment of the SR-520 are in yellow. Note the massive expansion of bus stations between 1995 and 2014.

The belief that the region's transportation infrastructure was inadequate originated from growing concern over the Seattle area's rapidly worsening traffic due to its population growth. At the time, the existing Comprehensive Plan dated to 1981 and "was prepared during a period of rapid growth in transit ridership, which... slowed substantially, giving rise to changed conditions." (King County Resolution No. 6641) Seattle's congestion had gotten significantly worse since the 1980's, with an RTA pamphlet from the mid-1990's stating, "the number of trips people [made] around the region [had] increased 450 percent in the last 30 years" (Regional Transit Authority, 1995), and another RTA publication stating Seattle's traffic ranked behind only "major cities such as Los Angeles, San Francisco, Chicago and New York." (Regional Transit Authority, 1996) Further, "the geography of the region, travel demand growth, and public resistance to new roadways combined to further necessitate the rapid development of alternative modes of travel." (Regional Transit Authority, 1995)

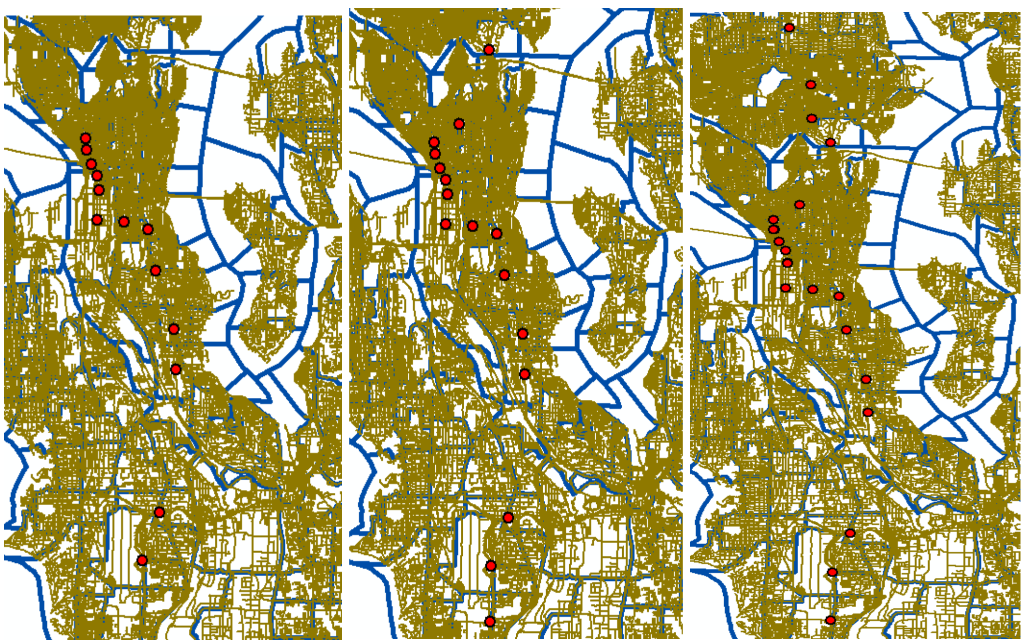
In 1995, RTA's first ballot initiative, *Phase I,* went before voters in a $6.7 billion (1995 dollars) transit package. A graphic of the Phase I proposal is available in Figure 10 in the Appendix. The *Phase I* proposal included adding High-Occupancy-Vehicle (HOV) lanes to existing freeways, the establishment of a commuter rail system, the creation of a 68-mile light rail system and expanded express bus services. The proposed commuter rail system would be 81 miles long and operate through seventeen stations, from Everett in the North to Lakewood in the South. The light rail system would operate on both street and subterranean levels and would stretch from Lynnwood in the North to Tacoma in the South. The light rail system would also cross Lake Washington. These proposals would take over sixteen years to complete. This $6.7 billion package would be paid for by a "four tenths of one percent increase in local sales tax and a three tenths of one percent increase in local license plate tab tax." (Regional Transit Authority, 1995) Voters rejected the *Phase I* transit package at the polls, with many citing concerns over its cost.

In response to the failed *Phase I* transit package, RTA proposed a $3.9 billion (1995 dollars) transit package titled *Sound Move* in 1996. The ten-year *Sound Move* initiative included the same infrastructure components as the rejected *Phase I* initiative, although each transit modal was less expansive: the proposed commuter rail system would now operate through 14 stations (instead of 17), whereas the light rail system would include 25 miles of track instead of 68 (Sound Transit, 1996). Figure 11 in the Appendix provides a graphic of the *Sound Move* ballot initiative. *Sound Move* was funded by the same increases in the local sales tax and license plate tab tax, but, with a smaller total price tag, residents would shoulder the associated tax burden for a shorter period of time. *Sound Move* was successful at the polls, and *Sound Transit* was created as the entity to execute the package.

In regard to the initiatives within the *Sound Move* package, this work only estimates the economic impact from the light rail system, not from the commuter rail line. There are several reasons for this. First, the commuter rail operates through preexisting heavy rail infrastructure, previously used solely by Amtrak and freight trains. Thus, isolating the impact of the heavily rail infrastructure poses a challenge. The light rail track is unique to its usage. Secondly, the commuter rail operates as an inter-city system, moving commuters between the region's central cities. The light rail operates as an intra-city system, moving commuters between residential areas and employment centers within the major metropolitan areas. The light rail also posts larger ridership figures than the commuter rail line in the aggregate, with the Central Link line reporting a ridership of 11,707,604 and the commuter rail line reporting a ridership of 3,812,040 in 2015 (Sound Transit, 2015). The commuter rail also only operates five days a week, during morning and evening rush hours. The light rail operates seven days a week, 20 hours a day.

The first light rail line approved within the *Sound Move* initiative began operation in 2003. Tacoma Link runs 1.6 miles through six stations in Tacoma, an industrial and shipping oriented city roughly 30 miles south of Seattle. Tacoma has not experienced the population

Figure 3 - Locations of Light Rail Stations in the Seattle Area from 2010 - 2021



The left panel shows the location of the original thirteen light rail stations that were operational as of December 2009. The middle panel shows the location of all operational light rail stations as of September 2016. The right panel shows the location of all light rail stations that are expected to be operational as of the end of 2021.

boom that has occurred in Seattle to the north and is a city of approximately a quarter-million people. Ridership on Tacoma Link has been fairly anemic with approximately 981,000 boardings in 2015 and the system posting declines in year-to-date ridership in 2009, 2013 and 2014 (Sound Transit Quarterly Ridership Report Archive, 2016). Tacoma

Link is free to ride due to budget projections that "fare collection costs would exceed the revenues that would be collected from charging fares." (Exit 133, 2016)

The main line of the light rail system, Central Link, opened in July of 2009 with twelve stations and connected Seattle's downtown region with Tukwila, a city approximately fourteen miles to the south. In December 2009, Tukwila was connected to the Seattle airport with a thirteenth station, bringing the total route to 15.4 miles. The location of these stations is depicted in the left panel of Figure 3. The thick lines in Figure 3 delineate census tracts, while the brown lines imposed on top of the census tracts are roads. Roads are included in this image to allow the reader to distinguish between land and water. The stations are depicted as red circles.

In 2016, the line was extended three miles north through the addition of two stations, with the terminal station servicing the University of Washington campus. An additional station opened south of the city at Angle Lake in September of 2016. The Central Link route is currently 20.4 miles long and operates through sixteen stations. The location of all operational stations as of September 2016 is displayed in Figure 3 in the center panel.

The final three stations within the *Sound Move* package are currently under construction and will extend the system from its northern terminus at the University of Washington to Northgate, a suburb and major shopping hub. The preliminary opening date for this extension, Northgate Link, is 2021. When discussing both the Central Link and Northgate Link lines simultaneously, I will refer to the system as the Link line. The state of the light rail system with these additional three stations is depicted in right-most panel of Figure 3.

Table 1 - Total Annual Boardings on Central Link

	2009[B]	2010	2011	2012	2013	2014	2015
Annual Boardings	2,501,211	6,989,504	7,812,433	8,699,821	9,681,432	10,937,099	11,707,604
Per Capita Boardings[A]	0.73	2.03	2.23	2.45	2.68	2.98	3.14
Per Day Boardings	6,853	19,149	21,404	23,835	26,524	29,965	32,076

A. Per capita figures are divided by MSA population using ACS 1 year estimates
B. 2009 reflects ridership from July 18th through December 31.
Source: Sound Transit Quarterly Ridership Report Archive.

Central Link has posted an average ridership increase of 11 percent annually for its first full six years of operation, as is displayed in Table 1 above. With this main rail spine established and becoming more popular every year, the additional routes in the planning stages will increase the system's accessibility to the region. In fact, within a week of opening the two stations that connect Capitol Hill and the University of Washington with the Central Business District (CBD), Sound Transit was discussing adding cars to the current trains to meet demand (Lindblom, 2016). Passenger boardings for the Central Link line are also high relative to other light rail systems' total boardings: Table 2 displays annual boardings in cities that have built light rail systems in the past 20 years. Although the newest system, Central Link's boardings per mile were 760,234 in 2015, the highest amongst major metropolitan areas with relatively new systems.

In 2008, voters approved a further initiative to expand the region's public transit system by authorizing the $13.4 billion *Sound Transit 2* package due to concerns over the growing population and the limited freeway capacity. *Sound Transit 2* will add "express bus and commuter rail service while building 36 additional miles of light rail." *Sound Transit 2* will

Table 2 - Light Rail Boardings in 2015 for Systems Built in the Past 20 Years

City	Passenger Boardings in 2015[A]	Passenger Boardings per Mile	MSA Population in 2015[B]	Year Opened
Seattle	11,707,604	760,234	3,733,580	2009
Phoenix	14,754,600	638,727	4,574,531	2008
Charlotte	5,072,300	533,926	2,426,363	2007
Minneapolis	23,003,400	191,700	3,524,583	2004
Houston	16,500,400	733,351	6,656,946	2004
Jersey City	23,014,800	213,100	20,182,305	2004
Salt Lake City	19,704,300	439,828	1,170,266	1999
Dallas	30,116,600	333,148	7,102,165	1996

A. American Public Transportation Association, Ridership Report Archives (2015)
B. MSA population obtained from ACS 1 year estimates (B01003)

expand light rail coverage south to the suburb of Federal Way, east across Lake Washington to the metropolitan area of Bellevue and further north to the suburb of Lynnwood. These lines will encompass a total of fifteen new stations. Although the locations of all stations have been announced, construction will not begin until 2018, with stations becoming operational in 2023. A graphic of the approved *Sound Transit 2* initiatives is available in Figure 12 in the Appendix.

In November of 2016, voters approved further expansion of the light rail system by passing a levy extending the system another 62 miles and 37 stations in a ballot initiative titled *Sound Transit 3*. Upon completion of the *Sound Transit 3* ballot initiatives, the light rail system will extend 116 miles across the region. Many voters who approved the ballot cited concerns over Seattle's growing population contributing to ever-worsening traffic, which is predicted to grow 30 percent by 2040 (Sound Transit Long Range Plan, 2014). The entire

Sound Transit 3 package will be completed in 2036, although individual components are set to be completed every two to three years. Other projects within *Sound Transit 3* include extended bus and train services, increased station accessibility for pedestrians and increased parking capacity at stations. A graphic of the approved *Sound Transit 3* initiatives is available in Figure 13 in the Appendix.

Although both Central Link and Tacoma Link have commenced operations in the Pacific Northwest since 2000, I only analyze the economic impact of Central Link. There are several reasons for this. First, the abrupt nature of the opening of the majority of the Central Link stations allows for distinct pre-operational and post-operational periods; thirteen of the sixteen Central Link stations opened in the second half of 2009, while the other three stations opened in 2016. Although this analysis is unable to capture direct responses to the additional three stations opening in 2016, I am able to evaluate direct responses for thirteen of the sixteen stations and will be able to capture preemptive responses for the three 2016 stations in the anticipatory regression specification (see *Section V*). The six stations in the Tacoma Link line became operational in 2003 and 2011, making an evaluation of its impact more difficult due to the incremental nature of its opening. Furthermore, policy implications derived from an analysis of Central Link are more amendable to extrapolation to other cities' systems than any policy implications derived from an analysis of Tacoma Link: the greater number of stations in the Central Link line and the higher population density of the locations of its stations allow for a greater number of people and businesses to be impacted by its presence. Additionally, the population of Seattle and total passenger boardings on Central Link are similar to figures posted by other cities with light rail systems; Tacoma's population and total passengers boardings are far below these levels.

Finally, Tacoma lies over 50 kilometers south of Seattle, making it distinct from Seattle geographically. An analysis of Tacoma Link is certainly warranted but is not necessary to include in an economic analysis of the impact of the light rail on Seattle. The light rail expansions included in *Sound Transit 2* and *Sound Transit 3* are unable to be included in this work as construction has not yet begun on these components of the system.

II.C. Land Use around Stations

Prior research indicates that expectations for growth around light rail stations must be met with complementary urban policies aimed at incentivizing growth in the intended radius (Cervero and Landis, 1995; Guiliano, 1995; Handy, 2005; Knight and Trygg, 1997; Transit Cooperative Research Program, 1995; Vesalli, 1996). A seminal guidebook directing city planners on the methodology to achieve the desired effect from transit investments states, “transit investments and services are incapable by themselves of bringing about significant and lasting land-use and urban form changes without public policies that leverage these investments and the pressure of such forces as a rapidly expanding regional economy.” (Transit Cooperative Research Program, 1998) Residential developments oriented around transportation hubs may encourage utilization of public transit by creating demand for the system: car ownership is generally not conducive to high density areas due to limited parking facilities and the often congested streets, whereas public transit is accessible and affordable. However, to accommodate residents without vehicles, zoning designations around stations must allow for a combination of residential and commercial presences in order to provide easy access to grocery stores, community necessities and pedestrian friendly routes.

The creation of public transit oriented communities such as these encompasses Seattle's Urban Village Strategy. The Urban Village Strategy involves creating compact communities in urban centers that contain both residential and employment opportunities. This strategy reflects an idea commonly known as 'smart growth' within the urban planning and sustainability literature. The American Planning Association's 2002 guidebook describes smart growth urban planning as creating "compact, transit accessible, pedestrian oriented, mixed-use development patterns." (American Planning Association, 2002)

One element of Seattle's Urban Village Strategy is Sound Transit's *Transit Oriented Development* (TOD) program. A TOD is a "land development pattern that integrates transit and land use by promoting transit ridership while supporting community land use and development visions" (Sound Transit, 2014) and directs growth adjacent to mass transit facilities. The TOD guidelines were established in 1996 after voters approved the *Sound Move* package. This plan was updated in December of 2012, with the new plan allowing Sound Transit to exercise additional authority in the early stages of development surrounding stations (Sound Transit, 2014). Within these new guidelines, one of Sound Transit's Real Property Disposition Priorities is listed as "encourage[ing] transit-oriented development, joint development, and public and private projects at and around Sound Transit facilities through early involvement in project planning and design." Several of the ancillary objectives within this priority are listed as "supporting economic development efforts, supporting state, regional and local growth plans, encouraging convenient safe multi-modal access to the transit system…, and encouraging creation of housing options including market-rate and affordable units." (Sound Transit, 2014).

One explicit goal of Seattle's Urban Village Strategy is to "ensure public agencies do not hold property where redevelopment is feasible" (City of Seattle, 2005) to maximize the number of residents in a station's immediate vicinity. This has involved relocating public agencies away from stations and, in some cases, rezoning entire blocks to allow for taller buildings with a higher residential capacity. However, Seattle's 2016 Transportation Management Plan claims that "rezoning has lagged somewhat in taking full advantage of the opportunity to leverage transit-oriented development in station neighborhoods." (Department of Transportation, 2016) Rezoning commonly occurs in tandem with attempts to increase densification in station areas, as is noted by economic impact studies in Atlanta (Bollinger and Ihlandfelt, 1997), San Francisco (Cervero and Landis, 1996) and Washington D.C. (Green and James, 1993).

According to the City of Seattle's Comprehensive Plan, the City "expects to add 70,000 housing units and 115,000 jobs" between 2015 and 2035. A 2016 report generated by the Seattle Office of Planning and Community Development notes that "because Seattle is a fully built city, most new development will occur on sites that already contain some existing residences or businesses." However, directing growth towards vicinities that are already established requires the displacement of existing firms and residents. During the planning phase of the Central Link Line, Sound Transit was forced to acquire property from residential and business owners along the line's path and within the vicinity of stations. Owners were reimbursed at a fair market value for their property, and relocation assistance was provided to businesses whose properties were acquired (Sound Transit and the U.S. Department of Transportation, 1999). Due to the development plan surrounding stations, zoning designations were occasionally modified (Sound Transit, 2014). Upon completion of the area's portion of the system, Sound Transit sold the previously acquired land to developers whose intentions aligned with the current zoning designations.

Although the region has implemented diverse policies to reduce driving and concentrate growth around mass transit, a 2010 report compiled by the Seattle Planning Commission found there was room for improvement in modifying zoning designations around stations. The report notes that, "depending on the specific location, zoning could be changed to accommodate additional households and jobs" and recommends "evaluat[ing[Single Family zoned land within transit communities to identify the opportunities for rezones to higher density or intensity as appropriate in each situation." Additionally, the report urges officials to "reconsider the general commercial zones in all transit communities," as this designation is not conducive to pedestrian access." (Seattle Planning Commission, 2010)

In response to lagged development in some station areas, Sound Transit included a provision within *Sound Transit 3* that specifically addresses the previous lack of coordination of zoning and development. During the construction of stations affiliated with the *Sound Move* initiative, Sound Transit purchased the minimum amount of land required for construction. Once a station became operational, this often left small, disjointed slices of land around stations that were undevelopable given their small size and dispersion (Department of Transportation, 2016). *Sound Transit 3* requires the expansion of staging sites, creating excess land around stations upon the completion of station construction. This excess land must then be sold for affordable housing purposes. The implementation of this land use strategy suggests that a future analysis of the economic impact of the light rail system may find larger results.

Anecdotal and empirical evidence suggest that, in order for the City to fully realize its Urban Village Strategy, the implementation of the excess-land strategy in *Sound Transit 3* is necessary. A popular Seattle publication, *The Stranger*, interviewed a couple who own a small convenience store next to the Mount Baker station, southeast of downtown. Although this couple anticipated a huge increase in customer traffic upon the light rail opening in 2009, these expectations have not come to fruition. They blame this lack of pedestrian traffic on the multiple small, undeveloped lots surrounding the station that were acquired for the construction of the station but are now vacant and are too small to build on – the exact catalyst for the excess-land requirement in Sound Transit 3 (Brownstone, 2016). In a similar vein, an analysis of San Francisco's light rail system "concluded that…zoning should have been coordinated and integrated into the original plan" in order to fully realize the stations' development potential (Graebner et al., 1979).

To mitigate displacement of the City's low-income population surrounding stations, the City has implemented incentive zoning policies in station areas. These policies give developers the ability to build beyond the height and density requirements as defined by the zoning designation in exchange for constructing affordable housing units or contributing to an affordable housing unit fund (Seattle Planning Commission, 2007). Beyond the increased availability of affordable units surrounding stations and the increased accessibility of these locations, living in close proximity to public transit provides many fiduciary benefits for low income individuals as well, as they need not budget for vehicle expenses such as car payments, insurance, gasoline and parking. However, the Community Development Manager at the Seattle Office of Planning and Community Development notes that, beyond using zoning designations to direct investment, spending public money to build affordable housing and incentivizing developers to construct affordable units through up-zoning, the City "[doesn't] have much real leverage" as to ensuring the supply of affordable housing remains adequate (Beason, 2016).

Access to transportation, especially in low income neighborhoods, is vital for the economic success of a community's constituents. In a recently released study from two Harvard economists, commute length is found to be a significant factor in a family's inability to escape poverty (Chetty and Hendren, 2015). This benefit of the increased accessibility of station locations runs in contradiction to the increased risk of displacement of low income residents associated with stations. As part of the *Sound Transit 3* package, a new station will be built in southeast Seattle. Many racial equity groups have advocated for the station to be located in a historically poor neighborhood, in order to provide this community with an economic stimulus. However, the City has eliminated this location as an option over fear of the displacement of current residents. One Seattle policymaker admits that they "don't have the tools today" (Person, 2015) to both ensure a community adjacent to a station reaps the benefit of the system's economic stimulus, while also protecting the existing community from the potential displacement that may occur.

Both the City and the State have attempted to implement policies that will result in congestion reduction. The 1991 Washington State Commuting Reduction Law required employers to provide alternatives to commuting alone in a personal vehicle to work for employees (Washington State Legislature, 1991). The law was renewed in 2006 with more stringent requirements, setting specific targets for certain cities and mandating businesses with more than 100 employees reduce the percentage of workers driving alone and to report their trends. This has resulted in many employers providing transit passes for employees and participating in city-sponsored carpool programs. Additionally, in 2012 the Seattle City Council approved a proposal that allows developers to reduce the number of parking spaces provided for residential units if the associated building is within a ¼ mile of a transit center (Seattle City Council, 2012). This not only reduces the cost of construction of residential properties within a ¼ mile of transit centers, but also frees up additional space for further development.

Depending on the span of data available post station operation, an analyst may deduce that the light rail has had a negative impact on housing units in station areas when, in reality, the data are simply displaying the cyclicality of the construction process. In order to create space for the construction of the newly operational Capitol Hill station, more than a dozen occupied buildings were destroyed in the immediate vicinity when construction began in 2009, including several apartment buildings (Frizzelle, 2016). However, 400 new units will be built on top of the Capitol Hill station in 2017 and several new apartment buildings are in planning stages directly across the street from the light rail, resulting in a net increase in units. To address the cyclicality of the construction process and the lag with which new structures are erected, I utilize two models in the estimation process: the primary model accounts for an impact from the light rail prior to the system's operation under the assumption that individuals, real estate developers and firms may react to the knowledge of the coming light rail station in the vicinity. The secondary model only accounts for an impact during the system's first full year of operation. Comparing and contrasting the estimates produced within each model allows for an understanding of the timing of responses induced by the system.

Although the region's ultimate goal is to increase densification and decrease congestion, land use priorities are not homogenous across stations. Stations further from the CBD encounter fewer restrictions on the total area the structure can occupy due to the decreased demand for space. For example, the Angle Lake station, the terminal southern point on the line that opened in September 2016, will have a 500-space parking structure immediately adjacent to the facility and a 1,000-space parking lot directly to the northeast. The construction of these large parking structures suggests developers expect many passengers boarding at the Angle Lake station to arrive in their own personal vehicle. If the expectation for the Angle Lake station is that individuals will arrive in a personal vehicle, then it is unlikely that the area immediately surrounding the station will experience the same degree of economic development that stations in dense, pedestrian heavy vicinities may experience. To control for the preexisting urban form around stations, I classify stations as either *'retrofit'* or *'new'*. Retrofit stations previously existed as bus stations and were retrofit with light rail infrastructure prior to the operation of the system. Retrofit stations exist in the dense CBD and have little, if any, adjacent parking facilities. New stations were built specifically for the light rail system and are not located in the CBD. I expand upon this discussion of station types in *Section V*.

II.D. Tolling in the Pacific Northwest

The daily capacity of the 1.4-mile SR-520 bridge was not intended to exceed 65,000 vehicles a day at its unveiling to the public in 1963. However, as of the early 2000's, the average daily crossings on the SR-520 bridge were approximately 100,000 and the bridge was in desperate need of repair (Washington State Department of Transportation, 2010). The Urban Partnership Agreement (UPA) was conceived of by the Department of

Transportation as an experiment in congestion mitigation techniques through the use of tolling, extending public transit availability and creating incentives for businesses to offer telecommuting options. In December of 2006, cities with heavy congestion were encouraged to apply for federal funding through the UPA program, with selected participants receiving financial assistance in implementing their congestion reduction strategies. The four cities selected for the UPA program were Miami, Minneapolis, San Francisco and Seattle. In 2009, the Washington state legislature passed House Bill 2211, which granted the state the authority to charge a toll on all vehicles crossing the SR-520 bridge. Beyond funding the bridge's needed maintenance, the implementation of the toll allowed the state to become eligible for funding through the UPA program. The toll commenced operations in December of 2011.

Table 3 displays the annual average daily crossings for both the SR-520 and the I-90, the two bridges traversing Lake Washington (see Figure 4). The implementation of the toll has coincided with a redistribution of traffic away from the SR-520 bridge to the I-90 bridge. The decrease in traffic on the SR-520 bridge in 2011 of roughly 4,500 daily crossings is likely a reflection of a sharp decline in traffic volume in December of 2011 when the toll first became operational. Daily crossings declined by approximately 33,000 on the SR-520 (a 35 percent decline) during the toll's first full year of operation. This decline in traffic volume on the SR-520 in 2012 coincides with an increase in daily crossings on the I-90 of approximately 14,000 (an 11 percent increase). These cross-lake traffic figures not only display a large substitution effect between the SR-520 and the I-90, but also indicate that total cross-lake traffic volume *was* reduced upon the implementation of the toll.

Table 3 - Average Daily Traffic Count[A] for Lake Washington Bridges

	2009	2010	2011	2012	2013	2014
SR-520	97,372	97,870	93,073	60,221	62,223	64,189
I-90	112,454	114,856	118,486	132,005	133,143	132,500
Total	209,826	212,726	211,559	192,226	195,366	196,689

A. Numbers represent eastbound and westbound travel.
Source: Washington State Department of Transportation, Annual Traffic Reports.

This disparity in the decrease in traffic volume on the SR-520 bridge relative to the increase in traffic volume on the I-90 bridge in 2012 suggests that many households did not simply substitute to the I-90, but may have adjusted their daily commuting behavior. These adjustments include carpooling, eliminating unnecessary trips, circumnavigating the lake or utilizing public transit. In order to ensure that public transit services are available for those who are unwilling or unable to pay the toll, Seattle has expanded its bus services in addition to building the light rail transit system. Upon the implementation of the toll in December 2011, "90 one-way peak period trips" along the SR-520 bridge were added (Schroeder et al., 2014). Table 4 displays the average peak period ridership on buses crossing the SR-520 bridge. This increase in access to public transit along with the increase in the marginal cost of driving a personal vehicle combined to "increase [public transit usage across the SR-520 bridge] 38 percent after tolling." Public transit ridership increased 23 percent across the I-90 bridge over the same period (Schroeder et al., 2014).

There are several types of tolling structures. The toll implemented on the SR-520 bridge is predetermined and is a function of the day of week, the time of day and the existence of an

Table 4 – Average Daily Ridership on the SR-520 Bridge During Peak Commuting Hours

Time Period	Direction	Summer 2010	Summer 2011	Summer 2012	% Change 2010 - 2012
6:00-9:00 a.m.	Eastbound	1,603	1,787	2,020	26%
6:00-9:00 a.m.	Westbound	3,098	3,586	4,236	37%
3:00-7:00 p.m.	Eastbound	3,313	3,954	4,675	41%
3:00-7:00 p.m.	Westbound	1,947	2,336	2,775	43%
Total		**9,961**	**11,663**	**13,706**	**38%**

Source: Seattle/Lake Washington Corridor Urban Partnership Agreement: National Evaluation Report.

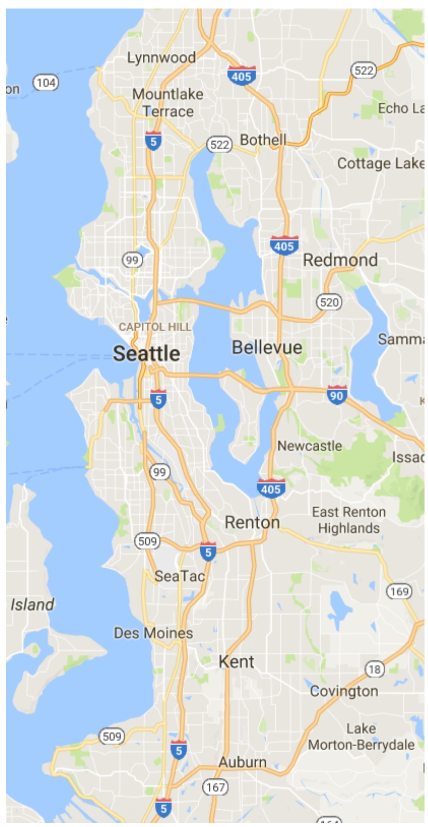
automatic payment account associated with a driver's license plate. The highest rate is charged during the morning and evening rush hours and is currently[3] $4.10 for drivers with an automated account and $6.10 for a driver without an automated payment account (Washington State Transportation Commission, 2017). Rates are available on the Department of Transportation's website and apply to all vehicles crossing the bridge, regardless of the number of passengers. Cost sensitive drivers are able to avoid the toll by utilizing the bridge during off-peak hours, reducing trips across the bridge or by using public transit.

High-Occupancy Tolling (HOT) charges drivers a fee to use lanes that are designated for high-occupancy vehicles, although the definition of high-occupancy varies by freeway segment. HOT prices for vehicles that do not meet the minimum number of occupants adjust automatically depending on traffic flow. Since the cost adjustment is automatic, drivers do not know the exact price they will face prior to entering the freeway. Vehicles carrying at least the required number of passengers are able to use the HOT lanes at no

[3] May 2017

cost. Vehicles without the minimum number of passengers required are able to avoid the HOT fee by staying in lanes designated for all traffic. Xie (2013) finds the HOT structure increases consumer welfare relative to other tolling schemes, since vehicles carrying the minimum required number of passengers are rewarded with expedited travel at no-cost and solo-drivers are able to self-identify if they are willing to pay to avoid congestion. The last type of common tolling structure is cordon tolling, which partitions off a certain section of a city (typically the CBD) and charges a fee on all traffic passing over this threshold. There is currently no cordon tolling integrated into Seattle's tolling structures.

Figure 4 - Map of the Seattle Metropolitan Area



The northern bridge crossing the large, central lake is the SR-520 (toll). The southern bridge crossing the lake is the I-90 (no toll). SR-167 tolling begins in Renton and extends south to Auburn. I-405 Express Tolling begins just south of the SR-520 - I-405 intersection and continues north to Lynnwood. Lake Sammamish is the body of water to the right of Lake Washington.

Besides the toll on the SR-520 bridge, two additional freeway segments in the region are now tolled. In 2008, SR-167 implemented a HOT structure that allows single occupancy vehicles to pay a fee to use express lanes for two or more passengers (Figure 4). The price of the HOT toll adjusts automatically from $0.50 to $9.00[4] in response to traffic conditions (Washington State Department of Transportation, 2008). Additionally, in 2015, a seventeen-mile stretch of I-405 began tolling (Figure 4). Vehicles with two or fewer passengers are able to pay a toll to use the express lanes intended for vehicles with three or more passengers. This toll also adjusts based on traffic-conditions and is $0.75 to $10.00[5] (Washington State Department of Transportation, 2015). Both these toll structures allow individuals to opt-out of the toll if they value the expense of the toll more than their time spent idling in traffic. However, individuals who value expedient travel or who are in extenuating circumstances are able to pay to avoid the heavy congestion. The SR-520 bridge serves as the unit for the toll analysis, and I do not analyze the tolled segments of the SR-167 or the I-405 since individuals are able to avoid these tolls if they choose.

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[4] As of May 2017
[5] As of May 2017

III. Literature Review

III.A. Light Rail Transit in the Literature

The literature has generally found that the implementation of light rail transit can positively impact regional density by concentrating growth around stations, although this is contingent on several criteria (Handy, 2005). First, the region must already be experiencing both economic and population growth in order for the redistribution of growth to occur in its intended locations (Cervero, 1984). Policies must then serve as a catalyst for growth by directing and encouraging investment in the desired urban form. Although Vesalli (1996) finds a positive impact on housing growth around stations, she cautions "these land use impacts of transit are not accidental, nor automatic… the only substantial impacts of transit on land use are those that have been planned, and this planning entails a substantial investment of public sector resources and coordination." The types of policies that may provide an impetus for high density development surrounding stations involve rezoning, restricting parking facilities and subsidizing investment in the area (Vesalli, 1996). Finally, locations for stations should be chosen in order to maximize their availability to the community and potential for economic impact, and not in an attempt to minimize costs of construction (Handy, 2005). If these conditions are met, the area may experience a redistribution of growth toward station areas in approximately five years, according to a highly-cited work by Knight and Trygg (1977).

Although Knight and Trygg (1977) predict observable growth will not occur for five years post system implementation, findings supporting the supposition that light rail systems do, indeed, have a positive economic impact on a region are not contingent upon this time frame. Green and James (1993) investigate the economic impact of Washington D.C.'s

METRO system four years post system implementation and find a statistically significant increase in employment growth around stations. Dyett et al. (1979) also use four years of data to examine San Francisco's BART and find modest gains in housing densification and employment in station areas. Cervero et al. (1995) critiqued the limited time span of Dyett et al.'s work and reanalyzed the system 20 year after its inception, finding larger increases in the stations' impacts on housing densification and employment. Cervero and Duncan (2002) use a cross section of data and also find rent capitalization from station proximity, while Knapp et al. (2001) use four years of data *before* a new system began operating and find large increases in home values given proximity to newly announced station locations. Since higher density is associated with higher prices per foot of real estate, increases in the value of property may suggest an increase in density.

Studies with longer panels include Bollinger and Ihlanfeldt's 1997 analysis of Atlanta's MARTA system 11 years after its initial operation. Although Bollinger and Ihlanfeldt do not find a positive impact from MARTA on population density and employment density, they do find an increase in public-sector employment in station areas. Baum-Snow and Kahn (2000) analyze five cities that either expanded current light rail systems or began operating a new system between "the end of 1979 and 1988" using Census data from 1980 and 1990. Given that there is only one "before" observation and one "after" observation, these studies are unable to account for the adjustments in population and employment that occurred between the panel end-points and, instead, rely on only one year of data in which to evaluate the effect of the change. Regardless, Baum-Snow and Kahn find a positive relationship between proximity to stations and rent capitalization.

Quantifying demographic responses to increased transit access is not prevalent in the literature but is warranted given that different population segments may exhibit variations in the value they place on light rail transit. One of the few analyses of the differential impacts of light rail systems on demographics is contained in the aforementioned Baum-Snow and Kahn (2000) work. Baum-Snow and Kahn employ a logit model to determine the sensitivity of different demographics to the implementation of a new transit system. Their analysis finds that college graduates aged 22-34 and non-blacks have the highest propensity to forgo their prior means of commuting and substitute to the light rail, and increases in wealth increase the probability of relocation around stations. This paper hopes to add to the knowledge established by Baum-Snow and Kahn (2000) and further inform policy makers as to the demographic segments with the most potential to respond to transit expansions.

The radius measurement used to define station proximity within the literature typically takes on a value of a ¼ mile, although a ½ mile measurement is not uncommon. Bollinger and Ihlanfeldt (1997) use a ¼ mile ring when quantifying the economic impacts of Atlanta's MARTA system, and Bernick and Carrol (1991) also use a ¼ radius when determining the density impact from three light rail systems in California. Similarly, Untermann's 1984 work on city planning uses a walking distance definition of ¼ mile. Cervero and Duncan (2002) use proximity radii of ¼, ½ and 1 mile in a logit model analysis of the predictors of public transit usage, and Knapp et al. (2001) find rent capitalization within a ½ mile of Portland's stations. The primary regression specifications within this work use a ¼ mile radius measurement. However, results using a radius measurement of a ½ mile are available within the Appendix.

There are a variety of approaches used in attempting to quantify the economic impact of light rail systems. The complexity of transitions of the urban form and the inherent endogeneity in the question itself result in a diverse set of techniques. For example, Dyett et al.'s (1979) analysis of BART consists of interviews with individuals intimately involved with the project, photographic review of identical sites both before and after construction and changes in the absolute number of building permits granted. Although a unique approach, this methodology is unlikely to lend itself to precise measurements of the system's economic impact. Cervero et al.'s (1995) subsequent analysis of BART utilizing 20 years of data employs a matching technique that compares vicinities with and without light rail stations that are within 1 to 2.5 miles of each other and possess similar cross-streets. This type of analysis does not allow one to compare growth within station areas to the rest of the region but, instead, only allows for comparison between the matched pairs. In order to determine if station areas are achieving a disproportionate degree of growth relative to the rest of the region, vicinities around stations must be compared to the rest of the study area.

Baum-Snow and Kahn (2000) use a continuous variable to measure distance from a tract's centroid to transit in their multi-city analysis. Upon the operation of a new transit system, they quantify the relationship between distance to transit and changes in transit usage and the degree of rent capitalization. Although Baum-Snow and Kahn compare the transit-induced changes with the rest of the study area, they do not incorporate zoning into their variable of interest, potentially introducing bias into the estimated coefficient. The work herein controls for many non-station influences that may impact individuals' and firms' locational decisions and uses an annual data series that allows for a more accurate estimate of the system's economic impact.

III.B. Tolling in the Literature

There are very few empirical papers regarding the economic impact of tolling. This scarcity in the literature likely reflects challenging characteristics of the subject matter that are applicable to different genres within the realm of tolling. Within the realm of congestion reduction and the maximization of consumer welfare, there is often a lack of sufficient data to properly estimate drivers' responses to the institution of a toll. However, the empirical literature regarding tolling has expanded with the introduction of dynamic pricing and electronic toll passes, as researchers now have the ability to exploit transponder data to determine changes in consumer welfare and price elasticities. The difficulty in the estimation of macroeconomic indicators' responses to tolling has not been alleviated with technological advancements as has congestion estimation, although simulation modeling has become more common. The inherent challenge that arises in quantifying the macroeconomic effect of tolling is the proper identification and delineation of appropriate treatment and control subsets. Since passengers on public transit vehicles are generally exempt from tolls, an individual is only impacted by the presence of a toll when driving a personal vehicle. Thus, those affected by a toll need not live near the tolled facility. This wide expanse of the toll's impact confounds the process of attempting to delineate geographical boundaries where the included subsets are homogenous other than their spatial relationships with the toll.

Although the empirical literature on tolling is sparse, there are many theoretical works dedicated to the subject. The root cause of congestion is the inherent public-good aspect of roadways. Coase (1974) discusses the dimensions of public-goods, namely their under-provision and overuse as they are both non-rival and non-excludable. The additional patronage of a road induced by its non-rivalry and non-excludability naturally creates negative externalities. Walters (1961) addresses this overuse by arguing that if efficiencies are optimized at P = MC and roads are public use, the result is overutilization. To address this overuse, Walters suggests prices associated with driving be raised through gasoline taxes and tolling apparatuses. The artificially low realized price of driving has implications for the sprawling urban form that began to dominate the landscape in the 20th century according to Brueckner (2000), who partially attributes urban sprawl to the "failure to account for the social costs of congestion." Although the problem of congestion is multi-dimensional, modeling indicates that consumers are responsive to increases in the marginal price of driving. Henderson's 1974 model of pricing of the usage of congested corridors suggests congestion tolling would induce a temporal redistribution of traffic and "per person costs (to travel) [could] decline," leading to a pareto improvement.

Since this paper does not assess drivers' responses to tolling or the induced change in consumer welfare, I do not dedicate a great deal to discussing the literature on these topics. However, several works have implications for the macroeconomic variables that I analyze. Xie (2013) finds consumer welfare increases when single occupancy vehicles have the option to pay to use carpool lanes (similar to the SR-167 tolling structure mentioned previously) relative to a peak-load pricing scheme in an analysis of transponder data from Minneapolis, Minnesota. This suggests individuals are willing to pay in order to decrease the amount of time spent in traffic, implying commuters may perceive a toll as a benefit due to its effect on congestion reduction and, thus, will relocate accordingly. Wang et al.

(2012) come to a similar conclusion in their use of the SR-167 and SR-520 "as study sites for simulation testbed developments to evaluate the toll impact on freeway operations," finding the SR-167 HOT lane structure allows for less choke-point congestion at freeway nodes (such as on and off-ramps) and "is more responsive to traffic conditions" relative to the current time-of-day pricing strategy used on the SR-520. Kalmanje and Kockelman (2009) create travel demand models specific to Austin, Dallas and El Paso and simulate consumer responses to the addition of toll roads. Roads near the tolled corridor experience higher speeds and regional Vehicular Miles Traveled (VMT) are reduced. However, roads adjacent to the tolled corridor in Dallas "are predicted to experience a substantial increase in their current VMT levels, suggesting that route shifts are substantial and will load connectors." Kalmanje and Kockelman (2009) also find a net increase in consumer welfare, noting that "welfare improvements fall with distance (to the toll) in Dallas and El Paso." This linear relationship is not present in Austin, with "neighborhoods near toll road termini gaining the most" and the effect dissipating in a non-linear fashion outside complex termini boundaries. The findings in Kalmanje and Kockelman (2009) suggest that not only could communities adjacent to the SR-520 experience welfare gains but the redistribution of traffic to corresponding corridors, namely the I-90, could decrease the welfare of these communities. These differing societal benefits and costs could serve as an impetus for population and employment shifting if one assumes households and firms seek to locate where the allocation of public goods best aligns with their preferences. Odeck and Brathen (2008) use survey data from Norway in conjunction with traffic counts to determine the short run elasticity of travel demand is -0.45, and the long run elasticity of travel demand is -0.82. I later utilize this larger long run elasticity to partially justify the estimation technique for the toll.

As mentioned above, empirical studies concerning the impact of tolling on macro-economic indicators are even scarcer than congestion modeling due to the difficulty in defining an appropriate impact area. To my knowledge, there is no existing analysis of the impact from a toll on population, housing or employment density that does not result from a simulated model. However, several additional works merit a brief discussion as they have implications for the study conducted herein. Pugh and Fairburn (2008) analyze the labor market and development impact of a new toll road (the M6) built in Britain. They find an increase in land values and a corresponding increase in employment along the toll corridor relative to a comparable un-tolled corridor. Using hedonic estimation techniques, Boarnet and Chalermpong (2001) examine the construction of new toll roads built in Orange County, CA in the 1990s. They find toll roads created accessibility premiums that are reflected in home sale prices. Gupta et al. (2006) find "location (residential and employment) choice changes in the long term" in simulated modeling of different tolling structures in Austin, Texas. However, all these analyses are conducted on new infrastructure that operate with a toll upon their initial commencement and not on preexisting infrastructure that instituted a toll. Thus, the analyses do not represent convincing quantifications of the economic impact from a toll as they are likely confounded by the increased accessibility that the completed road projects provide.

The non-simulated macro-variable focused papers discussed above generally find responses to the changes in accessibility of a location within several years of new infrastructure becoming available. Pugh and Fairborn (2008) use nine years of data prior to the opening of the M6 and two years of data after the corridor's unveiling to come to the conclusion that the M6 increased land values. Boarnet and Chalermpong (2001) utilize data on all home sales in Orange County from 1988 through "the first two months of 2000." Construction on the tolls included in their analysis finished in 1993, 1995 and 1996, indicating the accessibility premiums estimated came to fruition in as little as three years. Similarly, I utilize three years of data post toll-implementation, indicating that quantifiable population and employment shifting may be attainable.

The methodologies used in Pugh and Fairburn (2008) and Boarnet and Chalermpong (2001) vary, although both exploit the natural spatial and temporal variation provided by the intervention's natural experiment qualities. Pugh and Fairburn (2008) utilize data on the value of land surrounding the M6 Corridor in England before and after the corridor's opening. The treatment group contains areas that are accessible by the new road, while the control group contains areas whose accessibility has not changed. To determine the sensitivity of responses, different boundaries of five minutes, ten minutes and fifteen minutes removed from M6 junctions are used. This approach is reflected in *Section V* in the determination of the various boundaries for the treatment and control subsets. Similarly, Boarnet and Chalermpong (2001) compare distance removed to the new toll corridors with the change in home prices under the initial supposition that they will "see house prices decrease with distance from the toll road in the later years…but not in the earlier years." As a robustness check, I also use distance removed from the tolled corridor to evaluate the impact of the toll. The results indicate it is not an appropriate measure for the study at hand.

As with any change in taxation, it is important for policy makers to have an understanding of the progressivity or regressivity of a new cost applied to consumers. According to Kain's

(1968) Spatial Mismatch Hypothesis, tolls are generally understood to be regressive since many low-income workers are unable to afford rents in commercial hubs and, thus, must travel farther for a daily commute. Plotnick et al. (2016) attempt to predict the financial impact of the SR-520 toll on "low-income and non-low income households" by mapping commuting patterns of low-income and non-low income individuals. Upon identifying twelve highway segments for potential tolling, Plotnick et al. (2016) determine that commuters using either bridge on a daily basis are “much less likely to be low income” than users of the other ten identified segments within their research, indicating a toll on either bridge “would be less regressive than a toll on any other segment.” Since African Americans and the elderly are disproportionately poor, I address the question of toll regressivity through the examination of changes in the prevalence of African American communities and the elderly within specified boundaries applied to the SR-520.

A major component of Seattle's acceptance of the Urban Partnership Agreement funds (UPA) was an agreement to conduct periodic evaluations to better inform future policy. I now discuss several studies that were produced in conjunction with the UPA. Pierce et al. (2014) use a panel survey dataset collected from households using either the SR-520 bridge or the I-90 bridge from periods both pre-and-post toll implementation. Both drivers and public transit users were included in the sample, with public transit users intercepted at Park-and-Rides or on-board public transit vehicles crossing the Lake Washington corridors. Surveys were sent to drivers' addresses from randomly selected license-plate capture photos while crossing either bridge. The survey responses indicated "shifts from SR-520 to I-90 were most pronounced among males, those in lower-income households, and those with less workplace schedule flexibility." Schroder et al. (2014) present the U.S.

Department of Transportation's final report on the UPA Program. Using a Washington State Department of Transportation survey, Schroder et al. (2014) find "32 percent (of respondents) indicated they had changed their time of travel." They also find "lower income groups eliminated a greater proportion of trips across Lake Washington than other income groups," aligning with Pierce et al.'s (2014) determination that low-income individuals were more likely to substitute to the I-90 bridge. Schroder et al. (2014) conclude the toll provided benefits of $203,240,696 in 2012. These benefits are the result of time savings, reduced "vehicle operating costs and reduced emissions." The cost of the toll system's construction and operation in 2012 was $115,250,100, resulting in a "net societal benefit of $87,990,596." Pessaro and Songchitruksa (2014) present results from another survey disseminated to riders on public transit vehicles on the SR-520 corridor both before and after the implementation of the toll. An analysis of the survey responses found 55 percent of respondents were influenced to utilize public transit because of the toll and 57 percent said their travel experience was improved post-toll. Pessaro and Songchitruksa (2014) also analyze "loop detector data on the SR-520 bridge" that was collected prior to the toll's institution and during its first year of operation and determine speeds increased 14 to 18 miles per hour after the toll's implementation.

This study serves as a needed addition to the transportation literature in that it provides a non-simulated analysis of key macroeconomic indicators in a natural experiment environment. Although Pugh and Fairburn (2008) and Boarnet and Chalermpong (2001) provide informative analyses, their methodologies are most applicable to theories on induced travel demand and do not offer the literature any credible conclusions on the impact of tolling. Further, the stated preference surveys conducted as a part of the UPA do not equate to a revealed preference assessment of tangible responses.

IV. Study Area

Following Baum-Snow and Kahn (2000) and Voith (1998), the study area includes all tracts that lie within a 25-km radius of Seattle's CBD. In considering the radius, I attempt to maximize the percentage of individuals commuting to the CBD without diluting the interventions' impacts by creating too large of a geographical extent. The minimal possible radius from the CBD that will include all Link stations that were either operational or under construction in 2014 is 20-km. The maximum possible radius that will restrict the study area to only including Link stations (excluding Tacoma Link stations) is 30-km. I also include Lake Washington in its entirety to capture residents and firms living at all possible locations relative to the two transversal bridges.

Both the light rail system and the toll are likely to have an impact on individuals commuting to the CBD. Due to the condensed nature of the light rail stations near the city center, the availability of a new transit option that allows individuals to forgo a congested commute and expensive parking may be most appealing to individuals who work in or near the CBD. Individuals on the east side of the lake who commute to the CBD will be impacted by the implementation of the toll as well by either remitting a daily payment to use the SR-520, experiencing heavier traffic on the I-90 or changing their transportation mode to avoid the toll. Individuals on the west side of the lake commuting daily to the CBD will realize a change in traffic conditions around the two western bridge termini due to a redistribution of commuters between the two bridges

To proxy for the potential responsiveness to Seattle's transit changes, I calculate the percentage of individuals that commute to the CBD for radius sizes of 15, 20, 25, and 30-km using the 2000 Census Transportation Planning Package. I include the radius of 15-km so the marginal change in the percentage of individuals commuting to the CBD can be computed when the radius increases in length from 15-km to 20-km. These values are displayed in Table 5.

Column 2 shows the percentage of workers commuting to the CBD decreases as the base number of commuters increases through the expansion of the study area radius. As individuals are further geographically displaced from the city center, their best employment option is less likely to include a lengthy commute into the downtown area. Since there is a

Table 5: Percentage of All Commuters Traveling To the CBD for Work

Study Area Radius	Percent of Workers in Radius Traveling to the CBD[A]	Radius Population as Percentage of MSA Population[B]	Radius Employment as Percentage of MSA Employment[C]
15	17.5%	32%	47%
20	16.9%	40%	56%
25	16.5%	46%	58%
30	15.4%	51%	61%

A. Census Transportation Planning Package (2000)
B. Decennial Census, SF1 (2010)
C. Bureau of Labor Statistics (2010)

trade-off between increasing the size of the study area and the percentage of workers commuting to the CBD, I seek to find the optimal radius that will capture the maximum portion of the responsive population but also allow for meaningful extrapolation. In moving from a study area of 15-km to 20-km, the analysis gains 5 square kilometers of data, but the pool of individuals most likely to respond to these transit changes decreases by 0.9. Similarly, in expanding the study area from 20-km to 25-km and 25-km to 30-km, the pool of responsive individuals is decreased by 0.4 and 1.1, respectively. Given that the marginal decrease in the percentage of responsive candidates is minimized at 25-km, this is chosen as the study radius.

Column 3 and Column 4 show the 25-km study area contains significant percentages of the Seattle MSA's total population and total employment. The MSA figures reflect total population and total employment within the Seattle MSA in 2010. Any residents either working or living within the study area will impact area traffic and may contribute to others' motivation to relocate their residence or employment, use public transit or adjust their transportation behavior by other means. Beyond the 15-km radius, each expansion of 5 kilometers in the study area radius captures a lower percentage increase of the MSA's population, underscoring the concentration of residents near the radius' center. Employment is less dispersed from the CBD than population: 58 percent of the MSA's employment is captured within the 25-km study area, whereas 46 percent of the MSA's population is captured. Since a smaller portion of the region's population exists within the given radius than the region's employment, this may suggest the two variables will respond differently to the transportation interventions.

The chosen study area of 25-km from the CBD encompasses a total of 366 tracts that fall into two counties, King and Snohomish. Combined, King and Snohomish have a total of 546 tracts as of the 2010 Census delineations. The Link Line falls entirely within King County. One novel component of this work's analytical approach is the incorporation of tract zoning designations into the estimation technique. Unfortunately, there are no zoning designations for several tracts in Snohomish County that fall within the study area. This requires the elimination of ten tracts that are not able to be categorized as residential or nonresidential, resulting in a total of 356 tracts included in the analysis.

V. Data and Methodology

V.A. Acquisition of Dependent Variables

The set of dependent variables is constructed using Washington State's Small Area Estimates Program and the Puget Sound Regional Council's tract level data from 2004 through 2014. The dependent variables analyzed are population density, housing unit density, percentage of a tract's inhabitants that are African American, the average age within a tract, employment density and the percentage of public sector jobs. Total population, total housing units, the number of African Americans and the average age are obtained from Washington State's Small Area Estimates Program. Total employment per tract and public sector employment per tract are acquired from the Puget Sound Regional Council.

V.B. Creation of Proximity Variables for Light Rail

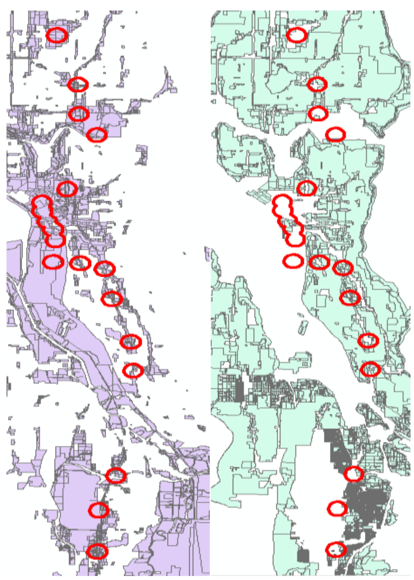
One of the contributions of this work is the creation of a unique dataset that uses geographical mapping techniques to measure the percentage of each census tract's residential or nonresidential area that lies within a ¼ mile of each of the light rail stations. The regression analysis measures the economic impact from the light rail system by comparing changes in 'station areas' to changes in the rest of the study area. I define 'station areas' as within a ¼ mile of a light rail station for several reasons. The primary reason is that the ¼ mile radius is established as the definition of walking distance within the literature and, in order to facilitate informed comparisons between studies, it is helpful to have a common denominator (Bernick and Carroll, 1991; Bernick and Cervero, 1997; Bollinger and Ihlandfelt, 1997; Calthrope, 1993; Cervero, 1994; Untermann, 1984). Individuals relocating to take advantage of the light rail system are self-identifying as either not owning a personal vehicle or as being strongly inclined towards public transit. Since most stations are not adjacent to parking lots, riders must walk or take other means of public transit to access stations. Thus, the likely impact area of the light rail only extends as far as the average person is willing to walk. Further, summary statistics comparing a ¼ radius around stations to an adjacent ring of a ¼ to a ½ mile from stations confirms that areas within a ¼ mile radius have experienced greater composition changes over the past decade than the further displaced ring (see *Section VI. Summary Statistics*). Finally, since the Seattle area is sprawling, with multiple employment hubs and suburbs, potential transit riders may be less willing to subject themselves to walking further distances in order to access the light rail's services. Thus, I restrict the size of the station impact area to a ¼ mile radius to ensure that the resulting estimate is not biased downwards by the inclusion of populations that are unlikely to respond to its operation. Results using a ½ mile radius are available in the Appendix.

At the time of this analysis, all operational light rail stations exist on the west side of Lake Washington and are oriented in a north to south pattern. In 2014, the end of the data panel, 25 tracts lay within a ¼ mile of at least one of the thirteen operational light rail stations. Many zoning designations allowing for both residential and business related purposes. I designate a segment of a tract as residential if its zoning specification allows for *any* sort of residential dwelling. Similarly, I designate a segment of a tract as nonresidential if it allows for *any* sort of commercial or business usage. Using an ArcGIS shapefile for Seattle zoning designations,[6] I determine that, of the land within a ¼ mile of all operational light rail stations in 2014, 42 percent is residential and 74 percent is nonresidential. I also determine that 41 tracts are within a ¼ mile of the nineteen stations that are either

[6] Zoning shapefile is from 2014 and obtained from data.seattle.gov

operational or under construction in 2014. Of this area, 39 percent is zoned as residential and 70 percent is zoned as nonresidential. Figure 5 provides a visual display of the area within a ¼ mile of all operational stations or stations under construction in 2014. The panel to the left displays nonresidential areas in purple and the panel to the right displays residential areas in green. Given that the land immediately surrounding stations is more likely to be nonresidential than residential, this may suggest that there may be more room for growth and transitions for residential purposes around stations since business usage may be at capacity.

Figure 5 - Zoning Designations for Areas Proximate to Stations



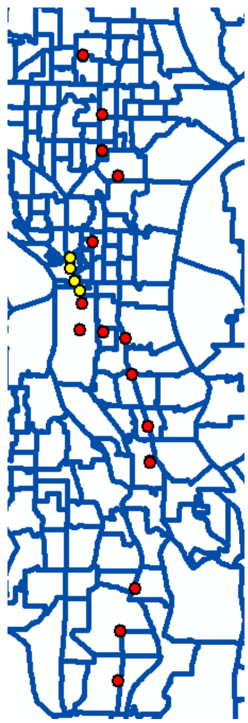
Each red ring delineates a ¼ mile around a operational stations and stations under construction in 2014. The panel on the left displays nonresidential areas in purple and the panel on the right displays residential areas in green.

The importance of the contribution of zoning to the potential economic impact of transit investments is recognized in the literature by both Bollinger and Ihlanfeldt (1997) and Vesalli (1996). Zoning could indicate either a limitation on growth or provide an impetus for growth: if a majority of a tract is already allocated for commercial purposes, then there may be little capacity to extend economic activity. Similarly, if the majority of a tract is zoned for commercial purposes but this land is underutilized, then the opportunity for growth exists and may be exploited in the event of a positive shock to demand for the particular location. McMillen and McDonald (1993) also conclude that, in order for a block to observe an increase in property values upon a transition to an entirely residential zoning composition, a strictly positive prior relationship must exist between residential zoning and property values.

Incorporating zoning into the estimation of stations' economic impacts will also direct expectations as to where growth could potentially occur. For example, if half of a tract's area falls within a ¼ mile of a light rail station but the entirety of this area is zoned for commercial purposes, then one would not expect an induced increase in the population of the tract because of the light rail. The lack of controlling for zoning in this scenario would result in a coefficient that is biased downwards as the model would not be accounting for the fact that the area in close proximity to the light rail is unable to experience an increase in population due to zoning restrictions.

To account for zoning designations within the ¼ mile rings around stations, I create a variable that measures the percentage of a tract's residential and nonresidential area within a ¼ mile of all stations (*Qtr-Mile*). I start with 2010 Census Tract shapefiles for King and Snohomish counties provided by the Puget Sound Regional Council and map all locations of stations that are either operational or under construction as of 2014. I then overlay this shapefile with zoning designations using data obtained from the King County GIS Data Portal and Snohomish County's website. If the dependent variable is related to population, housing or demographics, then *Qtr-Mile* reflects the percentage of a tract that is zoned for residential purposes. If the dependent variable is related to employment, then *Qtr-Mile* reflects nonresidential zoning. I also create a variable that simply reflects the percentage of each tract that is zoned as either residential or nonresidential.

Figure 6 - Location of Retrofit Stations



All nineteen stations that are either operational or under construction as of 2014 are depicted in the figure above. The fifteen new stations are depicted in red, and the four retrofit stations are depicted in yellow. The dark blue lines delineate census tracts.

The incorporation of zoning serves to guide my expectations as to what share of each tract could potentially be impacted by the presence of a light rail station. Note that a tract does not need to have a light rail station within its boundaries to have a non-zero value for *Qtr-Mile*: if any land within a tract lies within a ¼ mile of a light rail station, the associated value of *Qtr-Mile* will be greater than zero. The inclusion of either only operational stations or operational stations *and* stations under construction is contingent upon the regression specification.

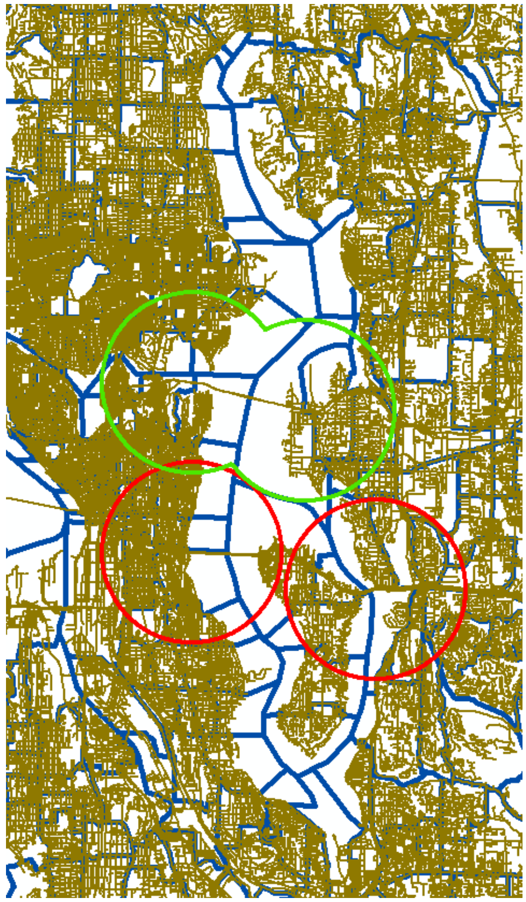
The usage of a continuous variable reflecting the spatial distribution of zoning designations in proximity to light rail stations gives the model increased flexibility as it is more exact than simply indicating that a tract's area does or does not meet given spatial criterion with a dummy variable. A tract's economic response to a sudden stimulus will be a function of the portion of its total area that is within a potential impact area. Ignoring this variation in a tract's spatial relationship relative to station locations that may provide an economic stimulus could result in a coefficient that is an underestimate of the system's actual effect.

To address the fact that four of the light rail stations existed as bus stations that began operation in 1990, I create an indicator to distinguish between these stations (*retrofit*) and the stations constructed solely for the purpose of the light rail (*new*). The retrofit stations are located in the heart of the CBD where density has been high for decades and there may be less of an opportunity for an expansion of economic activity (see Figure 6). Controlling for station type allows conclusions regarding the economic impact of the system to be drawn dependent on the preexisting location of the station. Only one tract has area lying within a ¼ mile of both a retrofit station and a new station. For this tract, the value of each station indicator is equal to the proportion of the tract's area within a ¼ mile of the given station type divided by the tract's total area within a ¼ mile to any station.

V.C. Creation of Proximity Variables for the Toll

The existence of an alternative bridge to cross Lake Washington allows for a natural comparison between the 'treated' toll bridge (SR-520) and the 'untreated' alternate bridge

Figure 7 - Comparison Group I Boundaries

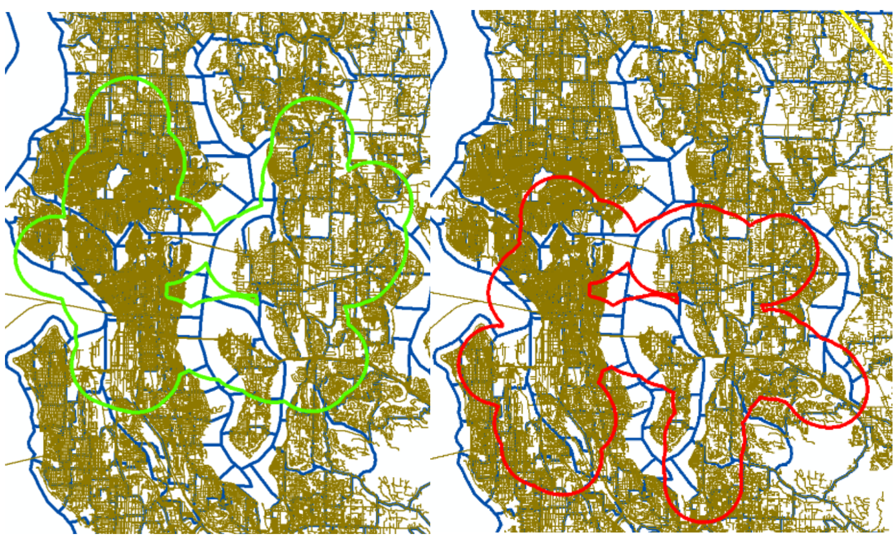


The two-mile impact area around the SR-520 termini is delineated in green, and the two-mile impact area around the I-90 termini is delineated in red.

(I-90). The area surrounding the SR-520 bridge is directly affected by the implementation of the toll: households may be displaced if they are unwilling or unable to pay the toll, while other households may seek to relocate towards the toll if the value of their time is greater than the cost of the toll. Additionally, household adjustments may induce businesses to change their location if a firm believes its ideal customer base has become more or less accessible after the toll intervention. The area surrounding I-90 will be indirectly affected by the toll: households that were previously located near the SR-520 may relocate towards the I-90 to avoid the toll, while households previously located near the I-90 may move towards the SR-520 to access its less congested corridors.

Using a methodology similar to the creation of the variables defining proximity to light rail stations, I define both narrow and broad boundaries around the SR-520 bridge termini and I-90 bridge termini where the analysis will attribute population and employment redistributions to the implementation of the toll. The spatial relationships encompass differing degrees of proximity to each bridge to determine the sensitivity of populations and firms to the relative accessibility of their chosen location. The impact of the toll within the two definitions of bridge proximity is estimated in separate regressions.

Figure 8 - Comparison Group II Boundaries



Tracts contained within 1.5 miles of a freeway ramp within five miles of the SR-520 bridge termini are delineated in green. Tracts contained within 1.5 miles of a freeway ramp within five miles of the I-90 bridge termini are delineated in red.

The first definition of bridge proximity consists of indicators for the percentage of a tract's area within two miles of the SR-520 bridge's termini and within two miles of the I-90 bridge's termini (Figure 7). Residents and employees located in tracts that are adjacent to the two Lake Washington bridges will be affected by the toll, whether this manifests as remitting payment for the SR-520 bridge's usage, experiencing lighter traffic on and around the SR-520 bridge or experiencing heavier traffic volumes on and around the I-90 bridge. As in the light rail analysis, each tract will have an associated value corresponding to the percentage of its residential or nonresidential area within two miles of each bridge's termini. This continuous definition of proximity to either bridge allows for variation in responses to the toll based on the entirety of a tract's spatial relationship with each bridge.

The potential impact of the toll is widespread since the toll only applies to personal vehicles traversing the bridge. Given that the mobility of the affected population is great, it is necessary to also analyze a broader area of impact relative to the first comparison group. The second boundary for examination contains all tracts with any area within 1.5 miles of a freeway ramp that is within five miles of each bridge's two terminal points (Figure 8). The difference in results across Comparison Group I and Comparison Group II will offer insight into the varying degrees of elasticity for the usage of the SR-520 bridge between these two populations.

To create the set for analysis for each comparison group, I use the previously mentioned King County and Snohomish County census tract shapefiles combined with zoning designations and overlay this with a GIS shapefile layer containing all transportation infrastructure provided by the King County GIS Data Portal.[7] I then map the coordinates of each bridge's termini into this layer. To create the relevant data for Comparison Group I, I draw a circle with a radius of two miles at each bridge's termini. I then intersect these circular sets with the shapefile containing the tract and zoning designations. Thus, each

[7] I do not have a corresponding transit shapefile for Snohomish County. However, the boundaries for both comparison groups do not extend into Snohomish County.

bridge has both a residential and nonresidential variable associated with its boundary. As in the light rail approach, residential proximity variables are used when the dependent variable is related to population, housing or demographics, while nonresidential proximity variables are used when the dependent variable is related to employment. To create the set for analysis for Comparison Group II, I first draw circles with radii five miles at each bridge's termini. After identifying all ramps on any interstates, state routes or highways within these five mile circular sets, I use ArcMap to generate additional circles with radii of 1.5 miles using the ramps as centroids. I then dissolve all boundaries, resulting in the second set of boundaries for analysis.

Since individuals living on the island in Lake Washington (Mercer Island) are only able to access the island using the I-90 bridge, 100 percent of Mercer Island is attributed to the I-90 variable in each comparison group even though 100 percent of its land does not have the required spatial relation with the I-90's terminal points in either categorization. Parts of Mercer Island's tracts also fall into the definition of proximity to the SR-520 bridge termini for Comparison Group II, but these proximity values simply reflect the observed portion of residential and nonresidential area meeting Comparison Group II's criterion.

A significant portion of the area in Comparison Group I is encompassed by the lake since the bridge entrances are the determinants of the boundaries of the set (see Figure 7). The area encompassing the lake contributes to the total surface area within each bridge's Comparison Group definition but does not contribute to its residential or commercial component. There are 31 tracts with any or all area within two miles of the SR-520 bridge's terminal points, and there are 39 tracts with any or all area within two miles of either of the

I-90 bridge entrances.[8] Of the land within two miles of the SR-520 bridge termini, 48 percent is residential and 10 percent is nonresidential. Of the land within two miles of the I-90 and the entirety of Mercer Island, 56 percent is residential and thirteen percent is nonresidential. The complete inclusion of Mercer Island within the I-90 variable may contribute to the higher prevalence of residential land surrounding the I-90, as Mercer Island is a heavily residential community. Recall that a vicinity is designated as residential if its zoning designation allows for any residential inhabitance, whereas a vicinity is designated as nonresidential if its designation allows for any commercial usage.

The narrow proximity definitions used in Comparison Group I result in minimal overlap between the tracts designated to each bridge. There is slight overlap between the circle centered at the western end of the SR-520 bridge and the circle centered at the western end of the I-90 bridge: there are seven tracts that possess area within two miles of both the I-90 and SR-520's west bridge entrances as the bridges are only 3.5 miles apart via Interstate 5. On the east side, the bridges are five miles via Interstate 405.

Since the criterion for inclusion within Comparison Group II is dictated by the region's highways, a much smaller portion of Comparison Group II set is attributed to the lake. There are a total of 157 tracts with proximity values for Comparison Group II - SR-520 and 150 tracts with proximity values for the Comparison Group II - I-90. As in Comparison Group I, the I-90 category has slightly more residential area than the SR-520 category, with 68 percent of the I-90 area being residential and 65 percent of the SR-520 area being residential. The SR-520 boundaries for Comparison Group II are more likely to contain

[8] This includes the five Mercer Island tracts that have 100 percent of their land contributed to the I-90 set, even though 100 percent of their land is not within two miles of the I-90 termini

nonresidential area than the analogous I-90 boundaries, with 32 percent of the SR-520 area zoned as nonresidential and 26 percent of the I-90 area zoned as nonresidential. However, there is significant overlap between the bridges' designated tracts given the set's expansive boundaries: there are 106 tracts that have some or all area meeting the spatial criterion for both the SR-520 and the I-90 within Comparison Group II.

V.D. Acquisition and Creation of Control Variables

Relative to other works within the transportation literature, the control set herein contains a vast spectrum of non-transit factors to help isolate the effect of the light rail and toll from other developmental determinants. Many prior studies have controlled for race, age, location in the CBD, income and percentage of a tract using public transit (Baum-Snow and Kahn, 2000; Dyett et al., 1979; Cervero et al., 1995; Green and James, 1993). These restricted sets of controls fail to reflect the multitude of factors that may affect locational decisions but are not related to the light rail or toll. In addition to race, age, and location, this work expands the control set to include education, unemployment, asking price of home,[9] income, commute length, percentage of population utilizing public transit and percentage of population below the Federal Poverty Line (FPL). These controls are obtained from the 2000 Census SF3 Sample and the 2009 through 2014 American Community Survey (ACS) 5-year-estimate datasets. I impute values for 2004 through 2008

[9] The Census and ACS data on housing prices are provided in bins (as opposed to raw values) for each tract. To determine a concrete data point for each tract, I take the median of each bin and multiply the number of homes in the bin by this midpoint. I conduct this procedure across all bins for each tract and then sum the value of all bins to obtain an approximate value of all homes on the market for each tract. I then divide out by the number of homes to find the mean asking price for a home within the given year. The highest bin for home asking price is one million dollars and greater. Given that this bin has no upper bound, I am unable to assign a midpoint. In order to account for these homes in the analysis, I assign a value of $3,500,000 for all homes in the highest bin. This procedure discounts homes with immense value but, given their relative rarity, it is unlikely to impact the results.

using a weighted average of the variable's 2000 Census value and the variable's 2009 ACS value. Values for 2009 and later reflect the ACS data. Values corresponding to 2000 tract delineations are adjusted to 2010 delineations using the Census Tract Relationship files. I also include the percentage of individuals commuting to the CBD for each tract using the 2000 Census Transportation Planning Package. This value is constant across all years for each tract, as the only available year of data corresponds to 2000.

To control for locational attributes, several additional variables are created in ArcGIS. I include a variable for the distance to the CBD to proxy for accessibility to economic activity. To generate the distance from each tract's centroid to the CBD, I first create a polygon for the CBD's boundaries within ArcGIS. I then find the distance from each tract's centroid to the nearest edge of the polygon. Additionally, all light rail regressions include a tract's distance to the nearest freeway ramp, as this captures a certain degree of accessibility of a location. The inspiration for the inclusion of freeway proximity also derives from the literature as it is often included in some variation (Bollinger and Ihlandfelt, 1997; Cervero, 2006; Cervero et al., 1995, Nelson, 1999). Finally, I create an indicator for tracts existing on the east side of the lake which is included in all analyses of the toll. Residents east of the lake may be more likely to be impacted by the toll since Seattle is on the west side of the lake, and they must cross the bridge daily if they work in the CBD. This indicator accounts for the five tracts on Mercer Island as existing on the east side of the lake since individuals must utilize the I-90 bridge to leave the island.

V.E. Economic Theory and the Seattle Area's Transit Expansions

The literature does not reach a consensus as to the economic impacts from light rail infrastructure or the operation of tolling systems (see *Section II*). However, given Seattle's supplemental urban policies aimed at concentrating residential growth around stations, it is likely that residential density will ultimately increase within a ¼ mile of stations while employment density will decrease. Any redistribution of population and employment density surrounding the SR-520 bridge termini may reveal households' and firms' preferences between the degree of disutility from the increase in the marginal cost of bridge usage relative to the decline in the amount of time required to both arrive at and traverse the SR-520 induced by the decreased traffic volume. The extent of any population and employment redistributions due to the implementation of the toll will be contingent upon the definition of bridge proximity used.

With the City's stated policy goal of orienting transit-oriented developments around stations, one may assume this will naturally translate into an increase in housing units surrounding stations once the light rail is operational. However, given the cyclicality of the construction cycle, the model may find a decrease in housing units within a ¼ mile of stations due to entire buildings being razed and rebuilt in order for the same amount of space to accommodate a larger population. Thus, a negative coefficient could reflect the cyclical nature of large construction projects and indicate an increase in population and housing in the near future. A negative coefficient could also reflect landlords' and developers' expectations that renters will not demand units adjacent to stations and, hence, are not willing to supply them.

The impact from the light rail on housing density will partially determine the interpretation of any corresponding change in population density in station areas. There are several reasons why households may value proximity to transit. The most obvious benefit from locating near public transit is the increased accessibility that is provided. Deriving from the increased accessibility of an area near transit is the decrease in the cost associated with transportation: public transit users need not budget for expenses such as car payments, gasoline, insurance and parking. However, households may also believe that residing near transit is a nuisance or even dangerous due to noise, crime or loiterers. Additionally, a metropolitan area in which citizens are heavily dependent on the personal vehicle or is sprawling in nature may not provide a sufficient base of potential transit users to capture any substantial increase in population density in station areas. If the model *does* indicate an increase in housing density within a ¼ mile of station *and* individuals value proximity to stations, the model will likely find a corresponding increase in population density in station areas. An increase in housing density without a corresponding increase in population density would likely indicate that proximity to the light rail is not valued. A decrease in both housing and population density in station areas could indicate residential displacement due to construction and would provide motivation for a similar analysis with a longer post-implementation panel. A decrease in housing density coinciding with an increase in population density in station areas could indicate evidence of the construction cycle and may suggest existing dwellings are housing a greater number of residents. A lack of any change in population density or housing density may indicate a change in the composition of the population within a ¼ mile of stations if the housing stock is inelastic: if individuals value the increased accessibility of station areas, this accessibility premium may be capitalized into housing prices, resulting in wealthier individuals residing in station areas but the total housing stock remaining unchanged. Various demographic groups may also differentially value proximity to transit, potentially leading to an additional change in the composition of the population immediately surrounding a transit facility instead of a net change.

Economic theory generally suggests that an increase in an area's accessibility increases employment density (Cervero et al., 1999 and Hansen, 1959). This increase in employment density could occur through several avenues: first, the assumed increase in pedestrian traffic due to stations' operations may increase the demand for commercial space in the immediate vicinity of stations, increasing the density of firms and, thus, total employment in an area. Further, if pedestrian traffic does increase in station areas, existing firms may require additional workers to ensure an adequate labor supply for the increased patronage. A firm near a transit station may also be more appealing to its potential labor force; workers may be more likely to both apply to and accept offers of employment at firms that are both easy and inexpensive to access.

The impact from the Seattle area's light rail system on employment density may run in contradiction to economic theory due to the intervention of City policy. Implicit in the City's urban policy goal of increasing residential development in station areas is a parallel decrease in available space for commercial and retail space: the City may rezone blocks from commercial to mixed-use to allow for residential dwellings above street level. This increased constraint on the availability of commercial space within stations' vicinities may displace current firms if they do not contribute to the neighborhood lifestyle or if they are unwilling to pay the higher rent associated with the decrease in supply of space. Additionally, firms with the intention of locating within the immediate vicinity of a station may find themselves crowded out by residential development if the City purchases buildings with the intent or achieving its urban revitalization goals. However, if the City is unsuccessful in implementing its transit-oriented-development policies, the model may find an increase in business establishments if residents are either unwilling or unable to relocate to station areas. Since the City has a greater degree of control over the location of government facilities than private establishments, it is likely that the light rail will decrease the percentage of public sector jobs within a ¼ mile of stations as policy makers seek to relocate public facilities to ensure residential usage is prioritized.

Predicting the directional effect of the light rail on the prevalence of African American communities and the median age is difficult as, again, economic theory and intuition provide explanations as to an impact in both directions. Given that African Americans are more likely to use public transit,[10] the light rail may result in an increase in the percentage of African Americans in station areas. However, if the value of the light rail is capitalized into home prices, African Americans may be displaced from these higher priced areas since they are disproportionally poor. Hence, any positive impact from the light rail on the prevalence of African American communities in station areas may be greatly mitigated if the proximity to stations is capitalized into rents. The same reasoning is likely to apply to the possible impact of the light rail on the average age within station areas: older individuals may be more likely to utilize public transit but, given their higher poverty rates, may be priced out of the area if rents increase. Also, individuals without children may be more inclined to utilize public transit, providing an additional catalyst for a change in the average age around stations. Although the economic predictions associated with many of the variables of interest are tenuous at best, the justification of this work lies with

[10] Bollinger and Ihlanfeldt (1997) find 23% of black households and 4.2% of white households do not have access to a personal vehicle within the Atlanta MSA.

quantifying policy makers' intentions as to the effect on the urban form, namely higher density and lower traffic volumes.

The impact from the toll on population and employment densification is likely to differ depending on the boundaries used to define the treatment and control areas. Comparison Group I is used to analyze the vicinities most likely to be affected by the toll due to their close proximity to the bridges. Neighborhoods and businesses located in tracts with positive values associated with the SR-520 for Comparison Group I will be directly affected by the toll, from being forced to remit payment every time they cross the SR-520 bridge to experiencing lower traffic volumes around and across the bridge (see Figure 7 above). However, given the desirable waterfront location of tracts that fall into the boundaries delineated by Comparison Group I, residents and firms in these areas may be more socially affluent and appreciate the implementation of the toll due to the associated decrease in traffic volumes. Thus, any potential decrease in density due to the toll in its most likely impact area may be greatly tempered due to the unresponsive nature of the population nearest the tolled bridge.

The second comparison group contains a much larger swath of the region and accounts for individuals who may live further away from the bridge entrances but have positioned themselves near a freeway entrance, perhaps indicating they utilize that freeway and the corresponding bridge more frequently than the other freeway and bridge (see Figure 8). The second comparison group may thus provide a more representative sample of the region's population since it reflects a more diverse geographical cross-section of the region and not only a narrow, wealthy subset as in Comparison Group I. However, as geographical displacement from the bridge increases, the likelihood that individuals will respond to the toll decreases, furthering the difficulty in appropriately delineating treatment and control groups for the toll.

As with the light rail, economic theory does not provide an unambiguous prediction as to a likely response pattern from area residents due to the toll, although the City hopes the increased marginal cost of driving a personal vehicle will induce individuals to reschedule or eliminate trips as well as substitute to public transit, resulting in a decrease in congestion. Theory predicts households will locate where the public goods and services provided coincide with their preferences and where rents reflect their budget constraints (Roback, 1982). The toll can be thought of as a tax that is paid in order to lower congestion levels. Population and housing density may decrease around the tolled bridge contingent on residents placing higher utility on the money necessary to cross the SR-520 bridge than the time spent idling in congestion. However, as the disposable income in an individual's budget constraint increases, the likelihood they will relocate to avoid the toll decreases. Given the distribution of income across the region, the wealthiest individuals reside in closest proximity to the toll, indicating that the savings in time from lowered congestion levels (see Table 3) on the SR-520 may be more valuable to these individuals than the forgone income used to pay the toll. Thus, in Comparison Group I, the model may display a slight decrease in the growth of population and housing density surrounding the SR-520 bridge if the toll discourages continued residential development due to investors' concerns regarding the demand for housing in neighborhoods with a high access cost. However, the model may also display an increase in population and housing density surrounding the SR-520 bridge if wealthy individuals prefer to remit the toll in exchange for the time saved in crossing the bridge. Since Comparison Group II contains a wide geographical extent, individuals residing in tracts with positive values for the SR-520 for Comparison Group II may find it sustainable to continue to reside in their same location but either substitute to the I-90 or to utilize public transit. However, regardless if some households choose to remain in their current residences located within SR-520 tracts in Comparison Group II, I-90 tracts within Comparison Group II may realize a higher growth rate in population and housing density relative to SR-520 tracts due to the lower cost associated with their access. The differences between the Comparison Group I and Comparison Group II results will provide insight as to the population shifting surrounding the lake, as it aligns temporally with the toll.

Theory does not provide an unambiguous prediction as to the direction of the impact from the toll on employment density. The toll could decrease employment density in vicinities within two miles of the SR-520 bridge if the decrease in traffic volumes around the SR-520 post toll implementation (see Table 3) signal a decrease in access to patrons. Any increase in the cost to access an establishment may dis-incentivize frequenting from patrons who value the money remitted to the toll more than the time saved in crossing the bridge. Establishments that cater to the very wealthy may not experience a decrease in customer patronage with the implementation of the toll, especially if wealthy individuals are incentivized to move towards the SR-520 bridge due to the decreased congestion. However, since government establishments often cater to the poor and disadvantaged, there could be a migration of public sector jobs from the vicinities immediately adjacent to the tolled bridge as government services relocate to ensure their continued availability.

It is less likely the toll will have a significant impact on employment density in tracts corresponding to either the SR-520 or the I-90 within Comparison Group II. If individuals seek to minimize their commute, then firms further from the lake are more likely to attract employees who are also further removed from the lake. As the distance to the lake increases, it becomes less likely that an individual's best employment option will exist on the opposite side of the lake, reducing the proportion of employees working at firms contained within the Comparison Group II boundaries that traverse the lake on a daily basis. It may be more likely the toll will initiate a redistribution of public sector employment within the Comparison Group II boundaries than a redistribution of total employment due to government establishments' need for accessibility to the poor and disadvantaged. However, as with the likely impact from the toll on shifts in employment density, the effect will likely be minimal due to Comparison Group II's wide geographical extent.

The probable impact from the toll on the prevalence of African American communities and elderly communities may be less ambiguous than its impact on population, housing and employment density. The toll is likely to cause a decline in the prevalence of African Americans and the elderly in tracts contained within two miles of the SR-520 bridge. Since African Americans and the elderly are disproportionately poor, any increase in the median income within two miles of the SR-520 termini will likely coincide with a decline in the prevalence of African Americans and the median age. Median income is likely to increase within two miles of the SR-520 bridge for two related reasons post toll implementation: first, the increased cost associated with accessing homes within this boundary may cause an exodus of low-income households from the area. Secondly, any households that self-select into residences within the SR-520 boundaries of Comparison Group I post toll implementation may be revealing they do not find the cost associated with crossing the SR-

520 to be burdensome, indicating the existence of disposable income within their budget constraints and, thus, possess high incomes. Hence, African Americans and the elderly may find themselves displaced from neighborhoods within two miles of the SR-520 termini. Since the geographical extent of Comparison Group II is so wide, it is unlikely the model will be able to quantify a demographic response to the toll within these boundaries.

V.F. Methodology

The economic impact of the light rail system and toll is estimated using two model specifications with different underlying assumptions regarding the reaction pattern of area residents and firms. The first specification allows the transportation intervention to impact the dependent variable prior to the change occurring and will henceforth be referred to as the '*anticipatory'* specification. This model operates under the assumption that individuals will anticipate the transportation interventions and will relocate accordingly to either access a good or avoid a cost. The secondary model accounts for an impact from the intervention only once it is operational and is referred to as the *'contemporaneous model*.' The impact of each transit intervention is first estimated separately and is then estimated in a combined approach.

With rent payments making up a significant portion of most individuals' and firms' monthly budget constraints, locational decisions may be considered long before any direct action is taken. To align the model with the most realistic estimation strategy, I build a planning aspect into the estimation of the transit features' impacts that enables the model to capture responses that occur prior to the deployment of the transit interventions. To accomplish this, I weight the variables of interest once the intervention is public knowledge. These weights are intended to capture the expectation of either added or diminished value of a given location contingent on the addition of light rail services or the implementation of the toll. This approach has precedent in the literature: Hess and Almeida (2007) find land capitalization around stations a year before construction began on the associated light rail system in Buffalo, New York, while Knapp, et al. (2001) find land capitalization occurring one year after future stations' locations were released but before construction began.

Residents and firms have several years in which to optimize their locations in regard to the light rail system as the locations of future stations are highly visible to the public due to their large construction sites. Information regarding the light rail system is also widely disseminated through the news media. The public had over seven years to react to the location of the original thirteen light rail stations prior to their opening: construction began in 2002 and the stations opened in July of 2009. In 2012, construction started on six more stations; three of these stations opened in 2016 and the remaining three will open in 2021.

Individuals had a shorter timeframe to respond to the implementation of the toll, although information regarding the decision to toll the SR-520 bridge was also highly publicized. The public first became aware of the consideration of a toll on the SR-520 bridge in early 2008 with coverage of the policy deliberation appearing in the region's newspapers, television channels and bulletins posted on all transit vehicles crossing the SR-520 bridge. The public appetite for the toll was gauged throughout the summer of 2008 with community meetings, online questionnaires and random phone surveys. In May 2009, Governor Gregoire signed the toll into law in House Bill 2211 (Washington State Department of Transportation. Tolling Background). The toll became operational on December 29, 2011.

To account for individuals anticipating the implementation of the light rail system or the toll, I apply weights greater than zero to the variables pertaining to the light rail or toll for all years in which the intended policy is widely known to the general public. For the light rail, I interact the station proximity variables with weights greater than zero and less than one once construction is underway on the tract's associated station. Weights applied to the station variables are not uniform across tracts since station construction and the commencement of services occurred in different years for the various subsets of stations. For tracts within a quarter mile of the thirteen original stations, this involves weighting 2004 through 2009. For tracts within a quarter mile of the three stations that opened in 2016, this involves weighting 2012 through 2014. This also allows for the three stations that will become operational in 2021 to be accounted for within the panel as construction on these stations also began in 2012. However, note that the full impact of the stations opening in 2016 and 2021 is not reflected in the data since the panel only extends to 2014.

Given that the public became aware that tolling would occur on the SR-520 in the near future in 2009, I include weights greater than zero and less than one for 2009 through 2011. There is no weight for 2008 since the public was not yet ensured that the toll would be implemented. Anticipatory weights for the toll are uniform across all tracts since there is no variation in the year of initiation of construction or operation.

Each weight is calculated using the difference between one and the difference between first year of operation of the transit intervention and the year in question, all divided by the difference between the year of announcement of the transit intervention and the first year of operation plus one. I add one to the denominator so the total span of years includes the year of system announcement. Weights are equal to one once the transit intervention has occurred. As an example, to construct weights for the tracts within a ¼ mile of the original thirteen stations, the procedure is the following:

<u>Equation</u>	<u>Year</u>	<u>Weight</u>
(1-(2010-200`x')/((2010 – 2002) + 1)))	2004	*(1-(2010-2004)/9))=3/9*
	2005	*(1-(2010-2005)/9))=4/9*
	.....	.....
	2009	*(1-(2010-2009)/9))=8/9*
	2010	*(1-(2010-2010)/9))=1*
	…	...
	2014	*1*

Construction on the thirteen original stations reflected above began in 2002, allowing individuals to plan their locational decisions around the expectation of an operational light rail system for eight years. As the year of operation approaches, each weight gets larger, allowing for a greater response to be accounted for. In 2004, the beginning of the panel, only the most involved public transit advocates may relocate to a vicinity near a station to ensure they will enjoy easy future access. Thus, the magnitude of the anticipatory weight allows for 1/3 of any changes in the dependent variable in station locations in 2004 to be attributed to the light rail. However, in 2008, a wider swath of the population may have relocated to take advantage of the system due to its imminent arrival. Hence, the weight allows 7/9 of the dependent variable’s changes in station locations to be assigned to the light rail. The procedure is analogous for the three stations that opened in 2016 and the three stations set to open in 2021, although each weight is a multiple of 1/5 and 1/10, respectively. A graphical representation of the station weights is available in the Appendix (Figure 14).

The process in calculating the weights is identical for the toll. In the year of announcement of the toll, any population and employment adjustments related to the toll are likely minor whereas, as the date of initial operation approaches, the potential response may be larger. The calculation of the weights for the toll is shown below. A graphical representation of the weights for the toll is also available in the Appendix (Figure 15).

Equation	Year	Weight
(1-(2010-20`x')/((2012 – 2009) + 1)))	2009	*(1-(2012-2009)/4))=¼*
	2010	*(1-(2012-2010/4))=1/2*
	2011	*(1-(2012-2011)/4))=3/4*
	2012	*(1-(2012-2012)/))=1*
	…	...
	2014	*1*

The anticipatory model may not be equally applicable to both the transit interventions: residents and firms may be more likely to adjust their locational decisions prior to the opening of light rail stations than the deployment of the toll. Relocating to a station area prior to the deployment of light rail services ensures a household will find living quarters they deem acceptable; waiting too long could terminate this possibility due to the spatial constraints surrounding stations. On the other hand, there is no direct benefit to relocating towards or away from the vicinities surrounding the SR-520 prior to the implementation of the toll; traffic is unlikely to be significantly affected on the SR-520 prior to the toll's deployment, indicating a household that places higher utility on time relative to money will not benefit if they relocate towards the bridge prior to the toll's operation. Households that seek to avoid the toll also have little incentive to react pre-emptively to the toll's operation: the expanse of locations in which the toll is easily avoided is vast, negating any spatial constraints. Further, money is not retained by relocating away from the tolled bridge several years prior to its operation versus immediately before its onset. Thus, the anticipatory model may be more applicable to estimating the impact from the light rail than the toll.

I also conduct a contemporaneous estimation approach. The contemporaneous model specification assumes individuals do not factor the impending transit intervention systems into their residential and employment decisions and only react to either system's operation once it has commenced. Without the anticipatory weights included in the prior model, this specification does not allow for a gradual response to the system, and population and employment shifts are only quantified upon the deployment of the intervention. Instead of the anticipatory weights, dummy variables are included indicating the operational status of the system. All other components are identical between the anticipatory and contemporaneous models.

V.G. Light Rail Estimation

The primary regression specification for the light rail is a first difference model and assumes individuals anticipate the arrival of the light rail and plan their locational decisions to maximize utility prior to its intervention. The anticipatory model is derived from a linear levels model of the form:

$$1)\quad Y_{it}=\beta X_{it} + \gamma S_i + \delta_1(\alpha_{it}*Retrofit_i*Qtr\text{-}Mile_i) + \delta_2(\alpha_{it}*New_i*Qtr\text{-}Mile_i) + \mu_{it}$$

where i indexes tracts and t indexes time. X are observable time-variant controls and S are observable time-invariant controls. The variables contained in X are age, percent black, education,[11] income, unemployment, commute length, home value, percent below the FPL and percent using public transit. Lags are applied on percent black, average income, poverty and the unemployment rate to reduce the effect of endogeneity. I also include a lag of employment density when estimating the impact of the light rail on employment density. The time invariant terms contained within S are the value of the dependent variable in 2000, distance to the CBD in miles, distance to the nearest freeway ramp in miles, the percentage of workers commuting downtown in 2000 and the percentage of a tract that is zoned as either residential or nonresidential as of 2014. Residential zoning is used when the dependent variable being regressed upon is related to population, whereas nonresidential zoning is used when the dependent variable is related to employment. B, γ and δ are the parameters to be estimated.

δ_1 and δ_2 are the variables of primary interest and quantify the economic impact of the light rail dependent on station type. α_{it} is the weight associated with the station located within a ¼ mile of tract i in year t. α_{it} increases gradually until a station's year of opening and is equal to one once a station is operational. $Qtr\text{-}Mile_i$ is the percentage of a tract's residential or nonresidential area within a ¼ mile of any station. As before, the zoning designation taken into account is contingent on the dependent variable. *Retrofit* indicates the station proximate to a tract originally existed as a bus terminal until being retrofit with light rail

[11] Percent of the population with a bachelor's degree or higher degree.

infrastructure, whereas *New* indicates the station proximate to a tract was built specifically for the light rail system. All tracts' values for $Retrofit_i$ or New_i are equal to either zero or one, except one tract whose area lies within a ¼ mile of both station types. For this tract, *Retrofit* and *New* reflect the percentage of the tract's area within a ¼ mile of any light rail station that is within a ¼ mile of a retrofit or new station, respectively. The interaction terms measure the degree to which the light rail motivates households and employers to relocate to increase their accessibility to transit while controlling for a wide array of non-station influences. The usage of individual terms for each station type attempts to capture any potential disparity in responses to the light rail based on stations' preexisting urban environment.

The primary justification for the first difference approach originates from the assumption of the concavity of the utility function (Clark, 1998; Pratt, 1964; Rabin, 2000). If the average individual is more responsive to potential losses than potential gains, residents will be less likely to relocate to a vicinity offering a new service than they would be to relocate to avoid a new cost. Given the massive publicity surrounding the opening of the light rail, any relocations induced by the knowledge of the light rail may quickly dissipate once the system is no longer the focus of press attention in the region. This suggests there may be an initial shock in the growth of population, housing and employment in station areas but the subsequent growth rate is likely to converge to its prior level. Further, the ¼ mile radii surrounding stations do not offer unlimited development potential; commercial and residential units may only continue to be added until the block is at capacity. These spatial constraints further justify the use of a difference methodology as opposed to a levels specification. Finally, the usage of a first difference methodology is supported in the literature in Baum-Snow and Kahn's (2000) analysis of the economic impact of several cities' light rail systems.

Subtracting $Y_{i,t-1}$ from both sides of 1) and substituting yields the first difference of:

$$2.a)\ \Delta Y_{it}=\beta\Delta X_{it} + \gamma S_i + \delta_1(\Delta\alpha_{it}*Retrofit_i*Qtr\text{-}Mile_i) + \delta_2(\Delta\alpha_{it}*New_i*Qtr\text{-}Mile_i) + \Delta\mu_{it}$$

Due to the increasing value of α_{it}, the difference in α_{it} is non-zero for all years prior to a station's opening. α_{it} is equal to one once a station is operational, yielding a difference of zero. Assuming that μ exhibits a random walk, the first difference of μ will also be consistent with the random walk hypothesis. Since the fixed effects estimator relies on $t \rightarrow \infty$, the first difference approach is superior in this context due to the abbreviated panel (Wooldridge, 2015). The station interaction terms quantify the change in the dependent variable within a ¼ mile of the given station type while controlling for zoning designations. To control for the operation of the toll in December of 2011, I also run 2.a) with the addition of an indicator for the year 2012 or later.

The contemporaneous model for the light rail primarily serves as a robustness check under the assumption that the wide dissemination of information regarding the system is likely to motivate individuals to anticipate the light rail's operation and adjust their locations prior to its commencement of services. Since the contemporaneous model only accounts for operational stations, the additional six stations that were under construction in 2014 are not included. As in the light rail's anticipatory specification, I run the light rail's contemporaneous model as a first difference reflecting the assumption the system will induce a single shock to the growth rate of the dependent variable and the subsequent growth will return to its prior level. In the contemporaneous model, the anticipatory weight is replaced with a dummy variable indicating the operational status of a tract's associated station. The only period in which the change in the operational status of the system is non-zero is 2010. Thus, during the system's first full year of operation, the model captures an abrupt, temporary change in the growth rate of the dependent variable, indicating that individuals do not relocate due to the system's presence until it is operational and that the vicinities around stations do not offer unlimited growth potential. All other variables are identical to the anticipatory specification. I also run the contemporaneous light rail model with an indicator for the operation of the toll.

V.H. Toll Estimation

To quantify the effect of the toll, the estimation procedure will exploit the temporal and spatial variation created by the onset of the operation of the toll and the existence of an alternative bridge to cross the lake. This natural experiment created with the existence of a substitute bridge suggests the usage of a difference-in-differences model. Difference-in-differences models are used to estimate the casual effect of an intervention by comparing outcomes of the treated and control populations both pre-and-post intervention while controlling for the preexisting differences between the populations.

The values of the dependent variables exhibited variation at the I-90 and SR-520 bridge termini prior to the toll's operation (see *Section VI - Summary Statistics*) in both definitions of proximity as given by the comparison groups. Thus, regardless of the operation of the toll, one would expect the same relative degree of variation between the dependent variables at the bridge termini if anticipating a parallel trend. In this analysis, the 'treatment' group consists of all tracts that have positive values corresponding to the SR-520 bridge termini as defined by either Comparison Group I or Comparison Group II's boundaries. The ‘control’ group is defined analogously but contains all tracts that have positive values for the I-90 variables as defined by the comparison groups.

The differences-in-differences model for the toll also derives from a level specification of the form:

$$3)\ Y_{it} = \theta X_{it} + \gamma S_i + \alpha_1 \omega_t + \alpha_2 \text{Prox } 520_i + \alpha_3 \text{Prox } 90_i + \alpha_4 (\omega_t * \text{Prox } 520_i) + +\mu_{it}$$

where *i* indexes tract and *t* indexes time, as before. *X* and *S* are observable time variant and invariant tract characteristics that may affect regional population and employment density. All variables within *X* and *S* are identical to 2.a) other than the initial value of the dependent variable now reflecting its 2007 value, the inclusion of a variable indicating a tract's presence on the east side of the lake and the exclusion of a tract's distance to the nearest freeway ramp. ω_t is the toll’s continuous anticipatory weight and is greater than zero and less than one for 2009 through 2011 and is equal to one in 2012 through 2014. *Prox. 90* and *Prox. 520* are the percentages of each tract’s residential or nonresidential area that adhere to the boundaries defined by Comparison Group I or Comparison Group II. The first-difference of 3) yields the estimated model of:

$$4.a)\ \Delta Y_{it} = ß\Delta X_{it} + \gamma S_i + \phi_1 \omega_t + \phi_2 \text{Prox } 520_i + \phi_3 \text{Prox } 90_I + \phi_4 (\omega_t * \text{Prox } 520_i) + \Delta\mu_{it}$$

Note that, unlike in the light rail model, the first difference is not applied to any variables specific to the toll, namely *ω*, *Prox 520*, *Prox 90* and *ω*Prox 520.* The coefficients in Equation 3 estimate a level shift, whereas the coefficients in Equation 4.a estimate changes in the variables’ growth rates. *β,ɤ,* and *ϕ* are the parameters to be estimated. μ is an error term.

Assuming the typical concave utility function, individuals will be more responsive to losses than gains due to the decreasing marginal utility of wealth (Pratt, 1964). Thus, theory suggests maintaining the variable of interest as a level because the toll may permanently change the demand for residential and commercial units around the tolled bridge and not simply result in a one-time shock to demand. This increased responsiveness over the long run is supported by Odeck and Brathen's (2008) finding that the short run elasticity of travel demand is -0.45 and the long run elasticity of travel demand is -0.82, implying changes in behavior accumulate over time. If individuals exhibit a greater response in adjusting driving habits over the long run, then this also may reflect a willingness to relocate to facilitate a change in driving habits over the long run. Although a longer span of data post-implementation would be ideal, estimating the toll variables as a level instead of a difference allows the model to capture the households and firms whose preferences do not align with the tax structure of the area after the implementation of the toll. As before, I also estimate a version of 4.a with a dummy included for the commencement of the light rail's operations. This variable has a value of one in 2010 and later and captures the potential effect of the light rail.

As in the light rail anticipatory model, the contemporaneous toll model eliminates the anticipatory weights and, instead, accounts for the toll's operation with the inclusion of a dummy variable equal to zero for panel years 2004 through 2011 and equal to one in 2012 through 2014. Given the likely nature of the response to the toll, the contemporaneous model may provide a better estimation of the toll's impact than the anticipatory model; if individuals do not realize a cost or benefit associated with the toll prior to its operation, then there is little incentive to preemptively react to its approach. All other model elements are identical to the anticipatory specification. I also estimate the contemporaneous toll model with the inclusion of a dummy variable indicating the operational status of the light rail system, equal to one in panel years 2010 through 2014.

V.I. Combined Estimation

Given that both the light rail and toll could motivate households and firms to relocate, I also estimate the effect from the light rail and toll in a single model. Since individuals may be incentivized to locate near the light rail and to avoid the toll, accounting for both interventions and their likely impact areas within the same model may provide the most accurate estimation. There is no overlap between the ¼ mile rings around the light rail stations within the anticipatory model and the Comparison Group I proximity measurements, whereas there is almost complete overlap between the ¼ mile rings around the anticipatory stations and the Comparison Group II measurements (see Figure 16 and Figure 18 in the Appendix, respectively).

The combined anticipatory model is the following:

$$5.\text{a)}\ \Delta Y_{it} = ß\Delta X_{it} + \gamma S_i + \phi_1\omega_t + \phi_2 \text{Prox } 520_i + \phi_3 \text{Prox } 90_i + \phi_4(\omega_t * \text{Prox } 520_i) + \delta_1(\Delta\alpha_{it} * \text{Retrofit}_i * \text{Qtr Mile}_i) + \delta_2(\Delta\alpha_{it} * \text{New}_i * \text{Qtr Mile}_i) + \Delta\mu_{it}$$

All variable definitions are identical to their previous definitions. The initial value of the dependent variable contained within *X* reflects its value from 2000. I also estimate a combined contemporaneous model, with the anticipatory weights replaced with dummy variables indicating the initiation of system operation. Figure 17 and Figure 19 in the Appendix display the overlap between the stations included in the contemporaneous model and the Comparison Group I and Comparison Group II boundaries.

VI. Summary Statistics

VI.A. Summary Statistics - Light Rail

Table 6 provides insight into the transitions around Seattle's original thirteen light rail stations over the decade surrounding the operationalization of the system. Table 6 uses the literature's definition of walking distance (Bollinger and Ihlanfeldt (1997); Bernick and Carrol (1991); Untermann's 1984; Cervero and Duncan (2002)) and compares changes within a ¼ mile of stations (*station areas*) to areas between a ¼ mile and a ½ mile of light rail stations (*adjacent areas*). If proximity to light rail stations is valued, then one should observe greater increases in demand for housing within a ¼ mile to stations than within a ¼ to a ½ mile to stations. Although it is likely that firms will demand locations near public transit as well, Seattle's urban policy goal of situating residential communities around light rail stations may constrain economic development. Note that the comparison of 'station areas' and 'adjacent areas' within this section is not equivalent to the quantification of the light rail's impact that will occur in the coming regressions: the regressions compare changes in population, housing, demographics and employment within a ¼ mile of stations to the rest of the study area.[12] Additionally, the anticipatory regressions account for an impact from stations that are not yet operational. Regressions strictly inclusive of tracts possessing any residential or nonresidential area within a ½ mile of a station are included in Table 25, Table 26, Table 45 and Table 46 in the Appendix. The magnitude of the results decreases slightly and loses statistical significance upon restricting the sample to include

[12] Regressions using a proximity measurement of ½ mile to stations are available in Table 27, Table 28, Table 47 and Table 50 in the Appendix.

Table 6: Changes in Station Areas Versus Adjacent Areas

	Station Areas[A]			Adjacent Areas[B]		
	2004	2014	Change[F]	2004	2014	Change[F]
Total Population Density	12,632	14,535	15.1 %	9,383	10,047	7.1 %
Housing Unit Density	6,533	7,880	20.6 %	3,559	4,116	15.7 %
Employment Density	44,875	48,985	9.2 %	29,983	31,515	5.1%
Pct Public Sector Jobs	16.3%	14.8%	-1.5	19.3%	19.7%	0.4
Black	20.8%	20.5%	-0.3	21.8%	21.7%	-0.1
Average Age	38.0	39.6	4.2 %	36.8	38.3	4.1%
Unemployment Rate [C]	6.9%	9.4%	2.5	6.6%	9.7%	3.1
Below FPL[C]	18.7%	20.2%	1.5	16.7%	20.4%	3.7
Median Income [C, E]	$54,179	$56,345	4.0 %	$56,813	$55,215	-2.8%
College Degree or Higher [C, D]	26.5%	33.2%	6.7	25.3%	30.6%	5.3
Pct of Workers with a Commute 30 minutes or longer [C]	38.0%	42.1%	4.1	38.3%	43.7%	5.4
Commuters Using Public Transit [C]	21.3%	23.3%	2.0	18.6%	21.7%	3.1
Price Asked for Housing Unit[C, E]	$368,997	$600,835	62.8 %	$332,077	$590,002	77.7%

A. Station Areas are defined as areas within a ¼ mile of a station.
B. Adjacent Areas are defined as areas between a ¼ mile and a ½ mile of a station.
C. Imputed value
D. For population over 18
E. In 2015 dollars
F. Calculated change is equal to a percentage change for numerical terms and is equal to an absolute change for percentage terms.

only tracts with a positive percentage of residential or nonresidential area within a ½ mile of stations.

An increase in accessibility may influence an increase in demand for a given location (Hansen, 1959). However, given the proliferation of the automobile in the 20th century and the majorities of people who are almost entirely dependent on personal vehicles,[13] it is unclear if expanding public transit really *does* positively impact a vicinity's accessibility. Despite the region's sprawling nature, the figures in Table 6 suggest that households and firms not only rely on public transit as a means of transportation, but also value proximity to stations: population density and employment density grew at a faster rate within a ¼ mile of stations relative to the ¼ mile to ½ mile ring around stations. Despite station areas' initial population density being higher than that of the adjacent ring, population density grew at a rate of 15.1 percent in station areas relative to 7.1 percent in adjacent areas. Figure 23 in the Appendix provides a visual of annual total population (not population density) within a ¼ mile of both station types for all stations listed in the panel that are operational. I use total population rather than population density to give the reader an understanding of the trend in absolute population around stations.

Employment density is significantly greater than population density in station areas. Employment density grew at a faster rate in station areas relative to adjacent areas, at 9.2 percent and 5.1 percent, respectively. Although there was a net gain in total employment within a ¼ mile of stations over the study period, this was not a steady increase: total employment decreased sharply within a ¼ mile of both station types shortly before the system's operation. Figure 27 in the Appendix displays the trend in total employment (not

[13] In 2000, 86.7 percent of all commuters in King and Snohomish counties used a personal vehicle for transportation to work (Census 2000, SF3).

employment density) within a ¼ mile of all operational stations by station type over the panel.

Public sector employment is similarly prevalent in both station areas and adjacent areas at the beginning of the panel but experienced a decline over the decade in station areas. This decrease in public sector employment surrounding stations stands in stark contrast to Bollinger and Ihlanfelt's (1997) analysis finding an increase in public sector employment surrounding Atlanta's MARTA stations. This dispersion of public sector employment away from station areas may be evidence of Seattle's Urban Development Board's policy of creating additional space for residential usage around stations by relocating any governmental establishments in the vicinity. Additionally, if rent costs are driven up by an increase in demand for a particular location, governmental agencies may not be able to justify locating in these areas.

The prevalence of African Americans decreased within both station areas and adjacent areas, although this decrease was slightly higher within a ¼ mile of stations. If one assumes the relative increase in population and employment immediately surrounding the light rail is a reflection of an increase in demand, then some degree of rent capitalization is likely to be occurring. Since blacks are disproportionately poor, an increase in rents around stations may result in their eventual displacement from these vicinities.

Table 6 also indicates the increased accessibility of public transit may have a direct impact on the economic well-being of the surrounding community. In 2004, station areas had a higher rate of unemployment, a higher percentage of the population living beneath the FPL and lower median incomes than adjacent areas. The rate of prevalence of individuals with at least a college degree was similar between station tracts and adjacent tracts, although both areas were lower than the study area average of 42.6 percent in 2004. However, over the course of the panel, the unemployment rate grew more slowly in station areas than adjacent areas, and the percentage of the population living beneath the FPL grew at a rate less than half of the growth rate in adjacent areas. Additionally, median incomes increased in areas around stations and decreased in adjacent areas, while the prevalence of college degrees increased at a faster rate in station areas than adjacent areas.

Although all four economic indicators are similar in magnitude between station areas and adjacent areas in 2004, the improvement of these indicators of well-being in station areas relative to adjacent areas suggests that the ability to easily access transportation may have a discernible impact on attaining and maintaining employment, attending school and earning an acceptable income. An alternative explanation is that individuals sort themselves into residential locations partially based on the location's accessibility: individuals who are employed and attend school may be more likely to value an easily accessible location, therefore selecting residences with additional transportation options. This theory of residential sorting is supported by the larger increase in the prevalence of college degrees within station areas relative to adjacent areas.

Commute lengths and public transit usage adjusted in a consistent manner in both areas over the panel. Adjacent areas experienced a greater increase in the percentage of workers with a commute 30 minutes or longer. This coincides with greater growth in the percentage of individuals using public transit. Since riding public transit often requires walking between stops and waiting for services, the increase in commute length in adjacent areas could be partially attributable to an increase in the percentage of workers using public transit. The higher growth rate in public transit usage in adjacent areas may indicate that individuals are willing to travel farther in order to access the light rail system than they were willing to travel to access the bus system.

Both areas experienced substantial increases in home prices, although home values in adjacent areas grew at a faster rate than home prices in station areas. The larger increase in the price of housing units in adjacent areas may suggest that station proximity results in negative capitalization into home values, contrary to the prior interpretation that the decrease in the prevalence of African Americans in station areas could indicate displacement. However, the slower increase in home prices in station areas relative to adjacent areas may be a function of the higher population and employment density in station areas, indicating units must be smaller due to the implied spatial constraints. Compared to the increase in housing prices within the rest of the study area of 25.5 percent over the panel, this rapid increase in home prices within both ¼ mile and ½ mile of light rail stations suggests many less affluent residents may be displaced from station locations over time.

VI.B. Summary Statistics - Toll

Table 7 and Table 8 provide weighted summary information reflecting the distribution of tracts composing the two spatial designations defining proximity to the SR-520 and I-90 bridge termini that will be used in the coming analysis. The first set of tracts for analysis (Comparison Group I) contains all tracts with any portion of their total area existing within two miles of either bridge's termini, while the second set (Comparison Group II) contains all tracts with any portion of their total area existing within 1.5 miles of a ramp within five miles of either bridge's termini.

The years chosen in Table 7 and Table 8 reflect the year prior to the announcement of the toll and the last year in the panel. Since Comparison Group I contains areas within two

Table 7: Changes in Comparison Group I - Areas Within Two Miles of Either Bridge

	I-90[A]			SR-520[B]		
	2008	2014	Change[C]	2008	2014	Change[C]
Total Population Density[E]	3,711	3,933	6.0%	3,657	3,927	7.4%
Housing Unit Density[E]	1,694	1,807	6.7%	1,670	1,750	4.8%
Job Density[E]	2,719	2,555	-6.0%	2,972	3,252	9.4%
Unemployment Rate[D]	6.1%	5.9%	-0.2	3.9%	5.5%	1.6
Pct Public Sector Jobs	9.9%	10.4%	0.5	1.4%	1.3%	0.1
Black	9.2%	9.2%	0.0	2.6%	2.7%	0.1
Average Age	39.6	40.6	2.5%	39.4	40.4	2.5%
Below FPL[D]	8.3%	10.1%	1.8	6.9%	7.1%	0.1
College Degree or Higher [D, F]	54.6%	58.4%	3.8	70.6%	72.3%	1.7
Median Income [D, G]	$89,168	$94,231	5.7%	$119,257	$126,087	5.7%
Pct of Workers with a Commute 30 minutes or longer[D]	27.7%	30.0%	2.3	23.9%	26.4%	2.5
Commuters Using Public Transit[D]	12.8%	14.1%	1.3	11.9%	14.1%	2.1
Price Asked for Housing Unit[D, G]	$1,341,920	$1,570,276	17.0%	$1,381,554	$2,441,375	76.7%

A. Tracts within two miles of the I-90 bridge's entrance
B. Tracts within two miles of the SR-520 bridge's entrance
C. Calculated change is equal to a percentage change for numerical terms and is equal to an absolute change for percentage terms.
D. Imputed value
E. Per Square Mile
F. For population over 18
G. In 2015 dollars

miles of the specified bridge's entrances, the home prices and average incomes in this group are very high since many water-front homes or homes with lake views are included. The second comparison group may thus provide a more representative sample of the region's population since it contains individuals spread throughout the region. However, the results obtained from Comparison Group I and Comparison Group II may offer insight into the reaction and sensitivity of different socio-economic levels to this usage tax.

Several statistics in Table 7 may suggest reactions to the implementation of the SR-520 toll within two miles of the SR-520 bridge termini, although the relationship may be tenuous. Population density grew at a faster rate in the two-mile radii that surrounds the two terminal points of the SR-520 bridge than the two terminal points of the I-90 bridge. The metropolitan area of Bellevue has experienced an extreme population boom in the past decade which may account for a large portion of the growth displayed in the SR-520 population values. Additionally, the inclusion of Mercer Island in the I-90 group may be constraining the growth in both population and housing within two miles of the I-90 termini: Mercer Island is near capacity in terms of residents, and there is little additional space to add housing units and people. Despite this, the I-90 group posts a greater growth in housing unit density. Given the closer proximity to the CBD of the I-90 group, this could indicate an increase in the density of the inner city.

Although the percentage of African American residents did not post any degree of growth within the I-90 terminal bridge radii, the percentage of African Americans of 9.2 percent is higher than the study area average of 6.2 percent, likely due to its proximity to the CBD and its inclusion of several heavily African American neighborhoods contained within the western boundary of the I-90's radius. The terminal points of the SR-520 bridge post an increase in their non-white population, but the area remains relatively homogenous at the end of the panel, with only 2.7 percent of the population being African American.

The I-90 boundary has a much larger proportion of government jobs than the SR-520 area, likely due to its proximity to the CBD. Even with the already low proportion of public sector jobs around the SR-520 bridge termini prior to the implementation of the toll, the SR-520 tracts posted a further decrease in public sector jobs over the course of the panel. Government offices may feel that locating near a tolled bridge is not optimal, as it decreases their accessibility to lower income individuals.

Unemployment in both groups was relatively low, although unemployment in the SR-520 areas increased, while the unemployment rate in the I-90 areas decreased. The increase in the unemployment rate in the SR-520 termini could be partially attributed to the toll: low-income individuals may seek to find new employment if the location of their current position required them to pay the daily toll. Finding a new position would then require restricting their employment search to specific locations in order to avoid the toll or insuring their new position was accessible using public transit. This increase in the unemployment rate within the SR-520 termini is especially notable considering the major shifts in employment density over the panel; there were large increases in the total number of jobs per square mile in the SR-520 termini and decreases in the number of jobs per square mile within the I-90 termini. When the increase in the unemployment rate is considered in this context, the suggestion may be that the individuals included in these two comparison groups do not work in close proximity to where they reside.

Both groups exhibited changes in commuting characteristics in terms of commute length and mode of transportation. The percentage of workers with a commute 30 minutes or longer increased for both groups, although it increased faster in the SR-520 group. Individuals in the SR-520 group were also more likely to substitute to public transit, perhaps to avoid the toll fees. Given that public transit is generally more time consuming than driving a personal vehicle, the larger increase in commute length for individuals in the SR-520 group may be due to the lengthened commute times due to public transit usage.

The most notable change apparent in Table 7 is the increase of 76 percent in the asking price for homes in the SR-520 group. Given the toll's relatively high cost of $3.90 to cross the bridge in one direction, many new residents to the SR-520 termini are revealing they value their time more than their income, as they are willing to incur this additional cost of transportation in order to live in the vicinity. For a full-time worker, the toll amounts to $2,028 over a year. Thus, this may create a selection bias not only in the individuals who choose to live in this area but also in the prices of homes that are for sale. In choosing to live in this area after the implementation of the toll, households may be identifying themselves as preferring to pay to avoid heavy congestion, indicating they have a large amount of discretionary income. Thus, the increase in home prices in this vicinity may reflect the perceived benefit incurred to these households from the toll, namely, the significant decrease in daily traffic.

Table 8 displays summary statistics for Comparison Group II. A majority of the area discussed in reference to Comparison Group I is contained within Comparison Group II, since Comparison Group II is much larger in area and captures a more all-encompassing snapshot of the region. As before, the entirety of Mercer Island is accounted for in the I-90 designation, even though not all of its area is within 1.5 miles of an I-90 ramp.

Table 8: Changes in Comparison Group II - Areas Within 1.5 Miles of a Ramp within 5 Miles of Either Bridge's Entrance

	I-90[A]			SR-520[B]		
	2008	2014	Change[C]	2008	2014	Change[C]
Total Population Density[E]	4,153	4,503	8.4%	4,751	5,108	7.5%
Housing Unit Density[E]	2,035	2,208	8.5%	2,418	2,598	7.4%
Job Density[E]	5,170	5,196	0.5%	5,713	5,811	1.7%
Unemployment Rate[D]	5.5%	6.8%	1.3	4.8%	6.3%	1.5
Pct Public Sector Jobs	7.6%	7.6%	0.0	7.8%	7.9%	0.1
Black	5.9%	6.0%	0.1	4.1%	4.3%	0.2
Average Age	38.2	39.2	2.6%	38.2	39.1	2.4%
Below FPL[D]	8.8%	10.2%	1.4	7.7%	8.9%	1.2
College Degree or Higher [D, F]	52.7%	55.7%	3.0	56.4%	60.5%	4.1
Median Income [D, G]	$90,940	$92,892	2.1%	$90,213	$93,511	3.7%
Pct of Workers with a Commute 30 minutes or longer[D]	30.2%	33.7%	3.5	29.4%	32.1%	2.7
Commuters Using Public Transit[D]	12.2%	14.0%	2.2	13.2%	14.6%	1.4
Price Asked for Housing Unit[D, G]	$840,701	$1,104,630	31.4%	$841,261	$998,354	18.7%

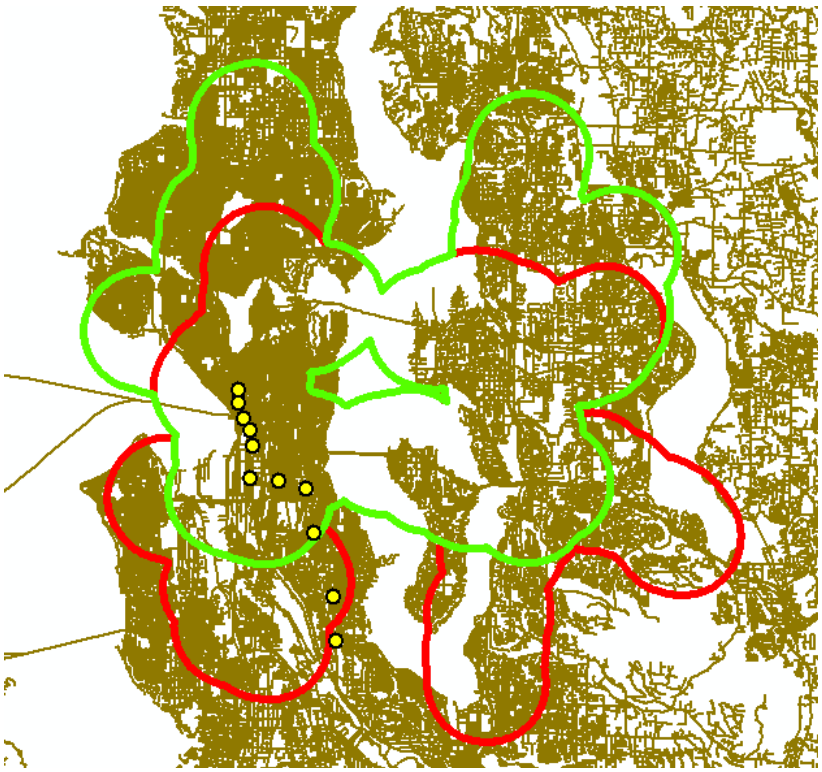
A. Tracts within 1.5 miles of a ramp within 5 miles of the I-90 bridge's entrance
B. Tracts within 1.5 miles of a ramp within 5 miles of the SR-520 bridge's entrance
C. Calculated change is equal to a percentage change for numerical terms and is equal to an absolute change for percentage terms.
D. Imputed value
E. Per Square Mile
F. For population over 18
G. In 2015 dollars

Although the SR-520 and I-90 bridge designations for Comparison Group II have a great degree of overlap, the area that differentiates the two bridges has distinct locational attributes that would allow for and encourage populations to respond uniquely to the toll. The area given the I-90 designation within Comparison Group II that is unique from the SR-520 designation extends to the southern end of Lake Washington on the east side of the lake, allowing for the inclusion of individuals who may prefer to drive around the southern tip of the lake as opposed to crossing the lake on the congested I-90 bridge. The I-90 group designation for Comparison Group II also extends east to the southern tip of Lake Sammamish, another wealthy, lakeside community. The area unique to the SR-520 designation for Comparison Group II does not extend to the northern tip of the lake to allow for the inclusion of individuals who may choose to drive north around the lake. However, the included area is far enough north that it is very unlikely these individuals would substitute to the I-90 to cross the lake.

Although population density and housing density are higher within the SR-520 designation in Comparison Group II, these densities are growing at a faster rate in the I-90 Comparison Group II designation. The populous residential communities of Kirkland and Shoreline in the SR-520 group likely account for a large portion of the population and housing totals, while the south-western portion of the I-90 group contains large swaths of industrial and aeronautical facilities that may limit the expansion of residential communities. The higher growth rate for population and housing densities in the I-90 group suggests populations may shift to the south in the coming years, with the toll being a potential factor behind this transition.

Employment statistics are also similar between the two groups in terms of the unemployment rate and the percentage of public sector jobs, although there are

Figure 9 - Comparison Group II Boundaries Relative to Operational Light Rail Stations



All light rail stations that were operational in 2014 are depicted as yellow circles above. The green boundary delineates all area within 1.5 miles of a ramp within five miles of the SR-520 bridge termini. The red boundary delineates all area within 1.5 miles of a ramp within five miles of the I-90 bridge termini. Roads are imposed in tan to allow the reader to distinguish between land and water areas.

approximately 500 more jobs per square mile in the SR-520 group. The northern portion of the SR-520 group contains several of the region's large malls which allows for high employment density in a concentrated area. As was mentioned previously, the prevalence of aeronautical firms in the I-90 group that possess massive domains but employ few workers per square foot of domain may be driving down the employment density in the I-90 group. When considered in tandem with the higher population and housing density in the SR-520 group, a picture of concentrated communities existing to the North and less concentrated communities existing to the South emerges. Both groups were hit with increases in the unemployment rate with the onset of the Great Recession at the beginning of the panel. As average incomes fell during the recession, it is possible the large shopping centers in the SR-520 group saw a decrease in daily traffic, requiring a reduction in the labor force and leading to an increase in the unemployment growth rate for the SR-520 group. The large aeronautical firms in the I-90 group may have also realized a decrease in the ordering of airplanes, contributing to the rise in the unemployment rate in the I-90 group.

Demographics appear similar between the two groups, with the greater prevalence of individuals beneath the FPL in the I-90 group potentially influenced by the group's higher proportion of African Americans. However, the minimal growth rate in the prevalence of African Americans in the I-90 group may suggest that African American communities are dispersing from this area and relocating in areas that are either captured within the SR-520 group or are not contained in either comparison group. The University of Washington falls into both the SR-520 and the I-90 designations, although its populous northern neighborhoods are only in SR-520 group: this may account for the SR-520's higher levels of education. Ages between the two groups are nearly identical and post similar growth rates over the panel.

Although median income is similar between the two comparison groups, it posts a higher growth rate within the SR-520 designation than the I-90 designation. This may be a manifestation of the previous supposition that those who are choosing to live in the vicinity of the SR-520 bridge termini perceive the toll as a benefit due to its decrease in traffic volumes. Individuals who prefer to pay in order to reduce commuting times are likely of higher incomes than those who are willing to have increased commuting times in order to avoid paying.

Once areas further away from both bridges are included in the computed means, one witnesses a change in commute lengths and public transit usage within the I-90 group relative to the SR-520 group. Whereas in Comparison Group I, one observes a larger increase in commute lengths and the percentage of commuters utilizing public transit within the SR-520 group, the I-90 group now posts larger increases in both variables. The back-up in traffic in the major arterials induced by the substitution of cars away from the SR-520 bridge to the I-90 bridge can occur several miles back from the I-90 termini and could be driving this increase in commute lengths. Also, the I-90 bridge group includes the southern tip of Lake Washington, which implies that this summary statistic includes individuals who are choosing to add miles to their commute by driving around the southern end of the lake instead of crossing the lake on the congested I-90 bridge or the tolled SR-520 bridge (see Figure 9). The increase in public transit usage in the I-90 bridge group could represent individuals opting for public transit in the face of ever increasing commute lengths, but it could also be partially attributable to the implementation of the new light rail system which is more easily accessible within the I-90 delineations of Comparison Group II.

The increase in home values in the I-90 bridge group was almost double the increase in the SR-520 bridge group. Since the area for Comparison Group II is much more expansive than Comparison Group I and follows the delineations of the major freeways, individuals in the SR-520 bridge group are not necessarily living in high income neighborhoods. Many of these individuals may have preferred the prior state of the SR-520 with additional congestion to the current tolled state with lighter traffic. The attempted toll avoidance may be decreasing demand for housing in areas that directly feed into the SR-520 bridge, serving as a drag on the increase in the associated home values.

VII. Population and Demographic Results

VII.A. Overview

Both the light rail and toll are associated with increases in densification in their proximate vicinities. When the impact from the light rail is accounted for prior to the system's operation, both new station areas and retrofit station areas experience large increases in population density and housing density. Once the impact from the light rail is only accounted for during the system's first year of operation, retrofit station areas experience only minor increases in population and housing densification, while new station areas observe a slight decline in population density and a negligible increase in housing unit density. The toll is associated with minor increases in population density within two miles of the SR-520 termini and larger increases in population density within 1.5 miles of a ramp within five miles of the SR-520 termini. However, relative population densities increase more within two miles of the SR-520 termini than within 1.5 miles of a ramp within five miles of the SR-520 termini. Housing density in both toll impact areas has not changed since the toll's announcement or operation. Neither transit intervention is associated with economically significant changes in the average age or the prevalence of African Americans within the associated tracts.

VII.B. Light Rail Estimation

The measured impact of the light rail on population and demographics is sensitive to model specification and station type. Within a ¼ mile of stations, the anticipatory model finds

statistically and economically significant positive impacts from the light rail on population and housing density. The anticipatory model also finds a decrease in age around retrofit stations and an increase in age around new stations, although these effects are not statistically significant. Effects from the light rail in the contemporaneous model are a fraction of the results found in the anticipatory model: retrofit stations experience a small increase in population density and housing density, while new stations experience a small decrease in population density and a small increase in housing density. The contemporaneous model also finds a positive, statistically significant increase in the average age around new stations.

Figure 22 and Figure 23 in the Appendix display the annual trend in total population (not population density) within a ¼ mile of all stations included in the anticipatory model and the contemporaneous models, respectively. The values displayed in Figure 22 (anticipatory figure) reflect the same weighting methodology used in the regressions. Additionally, recall that the anticipatory model and contemporaneous models include different subsets of stations: the anticipatory model includes all stations that are either operational or under construction during the panel, whereas the contemporaneous model only includes stations that are operational.

Table 9 displays the results of the anticipatory specification for the light rail using the ¼ mile proximity measurement. The light rail has had a large, positive impact on population and housing density within a ¼ mile of both station types within the anticipatory model framework. Δ *Anticipatory X New X Qtr-Mile* in Table 9 indicates a tract with 100 percent of residential area within a ¼ mile of a new light rail station would experience a statistically significant increase in population density of 2,571 individuals per square mile and an increase of 730 housing units per square mile from the commencement of new stations' construction through the first year of the system's operation. Although not as large as the increase in density surrounding new stations, population density and housing density have

Table 9 - Effect of Light Rail on Population Characteristics, Anticipatory Model				
	Dependent Variable			
	ΔPopulation Density	ΔHousing Density	ΔPct. Black	ΔAge
Independent Variable				
Δ Lag Black	5,269***	552.8		-0.439
	(1,523)	(974.8)		(1.417)
Δ Age	-162.6***	-87.48***	0.000325	
	(18.97)	(12.33)	(0.000220)	
Δ Education	207.8	103.9	-0.000455	0.176
	(147.0)	(97.14)	(0.00168)	(0.137)
Δ Lag Income	0.00233***	0.00125**	-3.94e-10	2.11e-06***
	(0.000871)	(0.000576)	(9.99e-09)	(8.09e-07)
Δ Lag Unemployment	219.3	-40.99	-0.00519	0.422
	(292.8)	(193.9)	(0.00335)	(0.272)
Δ Lag Poverty	-403.6**	-351.2***	-0.000664	-0.501***
	(186.1)	(123.2)	(0.00213)	(0.173)
Δ Commute Length	145.2	-25.76	0.00203	-0.128
	(126.3)	(83.68)	(0.00145)	(0.117)
Δ Pct. Utilizing Public Transit	109.5	101.8	-0.000515	0.00127
	(191.2)	(126.6)	(0.00219)	(0.178)
Δ Home Price	2.68e-05**	1.77e-05**	2.15e-10*	-2.83e-09
	(1.09e-05)	(7.24e-06)	(1.25e-10)	(1.02e-08)
Initial value	0.0102***	0.0110***	-0.00296***	-0.00786***
	(0.00146)	(0.00124)	(0.00110)	(0.00152)
Distance to CBD	-2.041	1.155	0.000133***	0.0106***
	(2.431)	(1.385)	(3.12e-05)	(0.00231)
Distance to Freeway	-1.052	-3.392	-0.000403***	0.0213***
	(6.284)	(3.560)	(7.99e-05)	(0.00580)
Percent Commuting to CBD	120.8	334.2***	-0.00125	0.306**
	(167.7)	(94.81)	(0.00203)	(0.145)
Pct. Residential	-85.29***	-68.00***	-2.28e-05	-0.0578***
	(20.68)	(11.65)	(0.000265)	(0.0193)
Δ Anticipatory X Retro X Qtr-Mile	1,524**	1,076**	0.00191	-1.064
	(732.4)	(465.3)	(0.00861)	(0.682)
Δ Anticipatory X New X Qtr-Mile	2,571**	729.8	-0.00498	1.368
	(1,118)	(701.9)	(0.0128)	(0.996)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

increased around retrofit stations as well: Δ *Anticipatory X Retro X Qtr-Mile* indicates that a tract with 100 percent of residential area within a ¼ mile of a retrofit station would experience a statistically significant increase in population density of 1,524 and a statistically significant increase in housing density of 1,076 upon the commencement of the system's construction through its first year of operation. These results are statistically significant at the 95th percent confidence level.

The results displayed in Table 9 are overestimates of any observable changes in population and demographics: the model's estimates are applicable to a tract with 100 percent of residential area within a ¼ mile of the given station type. Of the thirty tracts with any residential area within a ¼ mile of the fifteen new stations included in the anticipatory model and the four tracts with any residential area within a ¼ mile of the four retrofit stations, there are no tracts with 100 percent of residential area within a ¼ mile of either station type. Amongst the four tracts with any residential area within a ¼ mile of a retrofit station, the average percentage of residential area within a ¼ mile of a retrofit station is 49 percent while the minimum and maximum percentages are 2 percent and 97 percent, respectively. This implies the average tract with any residential area within a ¼ mile of a retrofit station may have experienced an increase in population of 747 residents and 527 housing units from 2004 through 2010. The average population density and housing density in the four tracts with any residential area within a ¼ mile of a retrofit station in 2004 was 2,881 residents per square mile and 1,473 units per square mile. This indicates the light rail system may be associated with a potential observed increase of 26 percent in population density and 36 percent in housing unit density from 2004 through 2010 in the four retrofit station tracts.

Amongst the thirty tracts with any residential area within a ¼ mile of the fifteen new stations in the anticipatory model, the average percentage of residential area within a ¼ of a new station is 9 percent while the minimum and maximum percentages are 1 and 44 percent, respectively. This indicates the average tract with any residential area within a ¼ mile of one of the fifteen new stations may have experienced an increase of 231 residents per square mile and 66 housing units per square mile from 2004 through 2010 for the nine new original stations and from 2012 through 2014 for the six new stations under construction during the panel. The average population density and housing density in the thirty tracts with any residential area within a ¼ mile of a new light rail station was 5,067 residents per square mile and 2,361 units per square mile in 2004, resulting in potential growth rates of 5 percent and 3 percent, respectively.

The differing methodologies used to quantify impacts of light rail systems makes direct comparisons between results challenging. However, I now discuss the magnitudes of others' findings to provide some additional context. Dyett et al. (1979) find small gains in housing densification four years after BART became operational, with "two-thirds of the 26 developers interviewed saying that BART was a "somewhat import" factor in their decision-making, and half stating that they would pay more for developable land near a BART station." Dyett et al. were able to identify 3,500 units whose "location, timing or density had specifically taken BART into account," although the distance removed from stations of these units is not discussed and the mechanism through which this occurred is unclear. Cervero et al. (1995) re-analyze the economic impact of BART twenty years after its commencement and find further evidence of densification around stations. However, these evolutions of the urban form around stations were uneven, with some stations experiencing large increases in a residential or commercial presence and other stations experiencing no changes. The entire Fremont corridor (one of four BART corridors) "accounted for one-third of all apartments and condominiums built within a half mile of the BART system," with the ½ mile radius around the Fremont station itself gaining 800 condos and another station gaining approximately 1,200 units. Other areas with notable impacts include the ¼ mile vicinity surrounding the Pleasant Hill station, which added over

1,800 housing units. Since Cervero et al. report their findings according to particular stations and not at the system-level, caution should be exercised when making comparisons between Cervero et al.'s findings and the findings herein.

As mentioned in *Section III*, instead of directly quantifying a change in population and housing densities in station areas, much of the literature has, instead, measured changes in home values and rents. Since there is a strong correlation between density and rental price per square foot, increases in rents likely imply increases in densities. Baum-Snow and Kahn (2000) find a decrease in distance to a new light rail system from three kilometers to one kilometer is associated with an increase in home values of $4,972. Knapp et al. (2001) find increases in property values within a ½ mile of light rail stations prior to the system's operation in a study of Portland's system: at the beginning of the panel, areas within a ½ mile of stations did not possess significantly different land values than the rest of the study area. However, four years prior the system's operation, land within a ½ mile of a light rail station was worth 71 percent more than land within the rest of the study area. Hess and Almeida (2007) also find "property located within a half-mile radius of rail stations is valued $2.31 higher…for every foot closer to a light rail station" within Buffalo, New York's light rail system. Al-Mosaind et al. (1993) find the price of homes within 500 meters of Portland's light rail stations increased 10.6 percent relative to the rest of the study area upon the system's operation.

To provide some additional regional context for the results, the average tract in the study area (excluding all tracts within a ¼ mile of a station) gained 168 residents and 83 housing units from 2004 through 2010. In 2004, the average population density in all non-station tracts was 2,291 residents per square mile and 1,014 units per square mile. Thus, the average non-station tract in the study area experienced increases in population and housing density of 7 percent and 8 percent, respectively.

In the Appendix, Table 30 displays results from a regression of the log of total population and total housing within the anticipatory model. Log regression results indicate that, although the net increases in population displayed in Table 9 are much larger around new stations than retrofit stations, the percentage change is larger around retrofit stations: population increased 10 percent around retrofit stations and 9 percent around new stations within the anticipatory model. The total number of housing units increased 16 percent around retrofit stations and 5 percent around new stations. The discrepancy between the predicted increases in total population and total housing units in the log transformation results displayed in Table 30 and the average density increases discussed above may be the result of several factors. First, the average population density and housing unit density values from 2004 are not weighted to take the relative portion of a tract's area that is within a ¼ mile of a station into account: I do this since the variables of interest in Table 9 are expressed in terms of the predicted growth within a tract, not within the ¼ mile radius itself. Secondly, the log regression results are based on total values and not on density values, making a comparison between Table 30 and the percentage changes relative to Table 9 difficult due to the lack of a common unit of measurement. Finally, the average values of population and employment density in tracts proximate to retrofit stations and new stations post huge variances across the tracts with any portion of residential area within a ¼ mile of the given station type, and this variance is not captured within the average value.

Table 29 in the Appendix displays the anticipatory model with a dummy variable included for the commencement of the toll's operations. Once the temporal operation of the toll is accounted for, the impact of the light rail on population density increases, and the impact on housing density is constant: a tract with 100 percent of residential area within a ¼ mile of a retrofit station would experience an increase in population density of 1,708 residents per square mile (from 1,524 in Table 9), while a tract with 100 percent of residential area within a ¼ mile of a new station would experience an increase in population density of 2,653 residents per square mile (from 2,571 in Table 9).

The variation in the light rail's impact on population and housing density by station type may reflect the preexisting urban form surrounding retrofit stations and new stations. The light rail coincided with a mass exodus of business establishments from the ¼ mile area surrounding retrofit stations, as is evidenced from the large coefficient on Δ *Anticipatory X Retro X Qtr-Mile* in Table 17 (see *Section VIII*). These vacant business establishments may then have been easily converted into residential housing units, hence the large increase in housing units relative to the increase in population. In order to accommodate a larger population around new stations, entirely new structures may have been needed to be built, creating a lag in the observation of increases in population and housing units. Additionally, with new building permits only granted by governmental officials, any new developments must be sanctioned as conducive to the region's growth plan. Thus, the increase in housing units surrounding stations may not simply reveal significant supply elasticity, but may also suggest that developers lack other lucrative opportunities.

African Americans did not exhibit economically or statistically significant responses to either station type. A tract with 100 percent of residential area within a ¼ mile of retrofit station may have experienced an increase in the percentage of African Americans by 0.2 percent, and a tract with 100 percent of residential area within a ¼ mile of a new station may have experienced a decrease in the percentage of African Americans by 0.5 percent associated with the light rail (column 3). Neither result is statistically significant. Bollinger and Ihlandfelt (1997) also do not find a statistically significant change in the prevalence of African American households within a ¼ mile of light rail stations in Atlanta. However, in column 3, *Initial Value* is -0.3 percent and highly statistically significant, implying African Americans dispersed very slightly from the communities they were located in during the year 2000. This could suggest either displacement or a blending of cultures.

Column 4 in Table 9 displays the two station types' differential attraction to residents of different ages. Δ *Anticipatory X Retro X Qtr-Mile* indicates a tract with 100 percent of residential area within a ¼ mile of a retrofit station would experience a decrease in the average age of thirteen months. Δ *Anticipatory X New X Qtr-Mile* indicates a tract with 100 percent of residential area within a ¼ of a new station would experience an increase in the average age of sixteen months.

The literature suggests that younger individuals may be more likely to change their commuting behavior upon the expansion of public transit availability: Baum-Snow and Kahn find individuals aged 22 to 34 increased their likelihood of using transit for commuting purposes from 13.8 percent to 15.9 percent upon the operation of Boston's light rail system and Dyett et al. (1978) determine that workplace proximity to BART was most import for workers under age 40. There are likely two components for the disparity in the appeal of station type to individuals of different ages: older individuals may not wish to reside in the very dense areas where retrofit stations are located and may be more likely to be financially stable and have the ability to locate in the suburbs. This supposition is supported by the statistically significant and positive effect of *Distance to CBD* on *Δ Age*

(Column 4) and the statistically significant and negative effect of *Δ Age* on both Δ *Population Density* and Δ *Housing Density* (Column 1 and Column 2). Secondly, older individuals may have a strong preference for light rail services relative to bus services. This is suggested by the fact that the new stations do not offer bus services but are strongly preferred by older individuals to retrofit stations. Since new stations only offer light rail services, older individuals may prefer the reduced congestion and chaos of these stations to light rail stations that also offer bus services and, therefore, are likely to have greater volumes of daily traffic. The same logic is likely to apply to the apparent appeal of retrofit stations to younger individuals: if one assumes younger individuals are more likely to engage in the night life of a large city and require transportation beyond daily commuting, then access to bus services that offer frequent, short trips between many different points of attraction may be appealing to younger residents.

Table 33 in the Appendix displays the impact from the light rail system on the change in the prevalence of young residents and the change in the prevalence of educated residents using the anticipatory framework. Young residents are defined as individuals under 30 years old, and educated residents are defined as residents with at least a college degree. Within a ¼ mile of each station type, the prevalence of young residents adjusted by nearly identical magnitudes but in opposite directions through the commencement of station construction through the system's first year of operation: Table 33 indicates the prevalence of residents under 30 increased by 4.4 percent within a ¼ mile of retrofit stations, whereas the prevalence of young individuals decreased by 4.5 percent within a ¼ mile of new stations. Both changes are highly statistically significant. The light rail system is also associated with a decline in the education level of residents within a ¼ mile of both station types, although neither change is statistically significant: the percentage of residents with at least a college degree decreased by 2.4 percent and 6.1 percent within a ¼ mile of retrofit stations and new stations, respectively.

Several locational variables generate impacts that allow for additional context regarding the distribution of population throughout the region. Δ *Lag Black* implies tracts with higher percentages of African Americans are strongly associated with denser population, reflecting that many African American communities are often in urban areas. If a tract's population adjusted from 0 percent to 100 percent African American, this would likely be associated with an increase in population density of 5,269 residents and 553 housing units (columns 1 and 2). *Distance to CBD* is associated with very slight changes in population and housing density, likely much smaller than one may expect (Clark, 1951). A one-mile increase in a tract's centroid distance to the CBD is associated with a decline of two residents per square mile and an increase of one housing unit per square mile. The highly metropolitan area of Bellevue, Washington is approximately ten miles from the CBD and may provide a neutralizing influence on what may otherwise be an economically significant decrease in population and housing density as one moves away from the CBD. Additionally, a higher percentage of individuals commuting to the CBD in 2000 is strongly associated with a larger increase in housing density (*Percent Commuting to CBD* in column 2, Table 9). Since jobs in the CBD may be more likely to be of a professional nature, this may suggest that developers are more responsive to housing demand in affluent communities.

The signs and magnitudes of many of the control variables in Table 9 coincide with expectations. However, I now discuss several controls that provide additional context as to some of the determinants of locational decisions. Slight agglomeration effects are implied by the positive 1 percent effect of *Initial value* on changes in population density and housing density, suggesting the prior existence of residences in an area provide a catalyst for motivating additional households to locate in the vicinity. These positive initial values also imply that Seattle's package of housing and urban development policies are succeeding in concentrating growth in previously dense communities. *Pct. Residential* has a highly statistically significant effect but only a minor economically significant impact on Δ *Population Density* and Δ *Housing Density*. The lack of an economically significant coefficient on *Pct. Residential* may suggest tracts with a higher percentage of residential area are likely to be removed from the city center, containing larger homes in low density neighborhoods. Thus, as a tract becomes more residential, population density and housing density decrease. Finally, increases in *Δ Pct. Utilizing Public Transit* are associated with small but economically significant increases in Δ *Population Density* and Δ *Housing Density.* This increase in public transit usage in areas experiencing growth may suggest that the availability of public transit is encouraging frequent public transit users to relocate to these vicinities.

The large increases in density around stations could suggest ongoing or imminent displacement of the City's urban poor: increases in density are associated with higher rental rates, implying existing communities could be priced out of the market as developers arrive to implement the City's TOD goals. Historical trends display an exodus of African Americans from the CBD between 1990 and 2000. One study finds "there were nearly three times as many black as white residents in the area [in 1990], but by 2000, the number of white residents surpassed the number of blacks for the first time in 30 years," (Henry,

2007) with African Americans posting "a net decline of 2,405 from the Central" Business District from 1990 through 2000. (Seattle Office of Planning and Community Development, 2016) This exodus of African Americans from the CBD coincided with dramatic increases in housing prices, with "a 1,270 square-foot single family, three-bedroom one-bathroom home … assessed by the county at a value of $5,000 in 1960, $190,000 in 2001, $262,000 in 2003, and $355,000 in 2005." (Seattle Office of Planning and Community Development, 2016).

This displacement of marginalized populations could repeat itself around stations if appropriate measure are not taken. Any positive shock to demand that is not met with a corresponding increase in supply will result in a higher equilibrium price. If increases in density in station areas lead to higher rents without any compensating interventions or without a sufficient housing supply increase, then African Americans may experience a displacement similar to their exodus from the CBD several decades ago. Although the City has ensured that affordable housing units continue to be constructed in station vicinities, the ongoing massive population boom in the Central Puget Sound region may be resulting in population growth outpacing the provision of new affordable units. The Central Puget Sound region grew by 25,000 to 65,000 residents each year within the panel (Puget Sound Regional Council, 2017), potentially placing a strain on developers' ability to provide an adequate supply of housing.

In the first two columns of Table 9, Δ *Income* is economically insignificant (but highly statistically significant) in predicting changes in population density and housing density, implying that changes in the wealth of a neighborhood are not associated with changes in the density of a neighborhood. The model also fails to find any relationship between Δ

Home Price and increases in population density and housing density. The lack of an impact of either Δ *Income* or Δ *Home Price* on changes in population density and housing density implies the City may have either been successful thus far in maintaining current populations within stations' vicinities or has been able to relocate individuals into and out of station areas while keeping the area true to character. However, City Councilman Mike O'Brien argues that displacement *is* occurring around stations, although the City's lack of planning around the line's earlier stations mitigated potential gentrification in these vicinities. O'Brien says, "While displacement is happening in Southeast Seattle, it could have been worse. That missed opportunity [the lack of planning] may have bought us more time. I don't want to pretend it's not already happening." (Person, 2015) O'Brien also notes that displacement is occurring to a much greater degree around the stations that opened recently, likely as a result of increased coordination with developers. Additionally, station areas are not the only vicinities experiencing increases in density within the study area: many suburbs and urban centers across the region are increasing rapidly in density, potentially influencing both the magnitude and the direction of Δ *Income* and Δ *Home Price*. The model may fail to identify these changes in the composition of the population living within the vicinity of stations due to the differing dynamics across stations resulting in a cancellation of the effect. The post system implementation panel may also not be sufficient to capture the changes in the characteristics of the station populations.

The estimated impact of the light rail is generally much smaller in the contemporaneous specification and there are occasional reversals of the direction of the effect. Table 10 suggests that, during the system's first year of operation, the light rail had a small, positive impact on population and housing density around retrofit stations, a negative impact on

Table 10 - Effect of Light Rail on Population Characteristics, Contemporaneous Model

	Dependent Variable			
	ΔPopulation Density	ΔHousing Density	ΔPct. Black	ΔAge
Independent Variable				
Δ Lag Black	5,220***	548.3		-0.464
	(1,526)	(975.1)		(1.415)
Δ Age	-161.3***	-87.94***	0.000325	
	(19.00)	(12.32)	(0.000220)	
Δ Education	211.9	105.0	-0.000439	0.172
	(147.2)	(97.26)	(0.00169)	(0.137)
Δ Lag Income	0.00228***	0.00123**	-4.16e-10	2.1e-06***
	(0.000872)	(0.000577)	(9.98e-09)	(8.09e-07)
Δ Lag Unemployment	235.9	-34.28	-0.00521	0.428
	(292.9)	(194.1)	(0.00335)	(0.272)
Δ Lag poverty	-399.0**	-350.5***	-0.000689	-0.495***
	(186.2)	(123.3)	(0.00213)	(0.173)
Δ Commute Length	133.3	-33.50	0.00203	-0.129
	(126.4)	(83.75)	(0.00145)	(0.117)
Δ Pct. Utilizing Public Transit	132.3	108.8	-0.000564	0.0129
	(191.1)	(126.6)	(0.00219)	(0.177)
Δ Home Price	2.70e-05**	1.76e-05**	2.14e-10*	-2.18e-09
	(1.09e-05)	(7.25e-06)	(1.25e-10)	(1.02e-08)
Initial value	0.0112***	0.0114***	-0.00295***	-0.008***
	(0.00139)	(0.00115)	(0.00110)	(0.00150)
Distance to CBD	-2.182	1.174	0.000133***	0.0104***
	(2.448)	(1.382)	(3.12e-05)	(0.00229)
Distance to Freeway	-1.074	-3.516	-0.00040***	0.0214***
	(6.334)	(3.557)	(7.99e-05)	(0.00576)
Percent Commuting to CBD	125.0	345.0***	-0.00127	0.296**
	(168.0)	(94.02)	(0.00202)	(0.143)
Pct. Residential	-89.02***	-69.54***	-2.46e-05	-0.057***
	(20.82)	(11.62)	(0.000265)	(0.0192)
Δ Station Operational X Retro X Qtr-Mile	118.3	123.9	0.000238	0.0530
	(146.4)	(96.72)	(0.00168)	(0.136)
Δ Station Operational X New X Qtr-Mile	-146.5	35.90	-0.00212	0.937***
	(374.3)	(247.4)	(0.00429)	(0.347)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

population density around new stations and a negligible impact on housing density around new stations. Older individuals continue to display an inclination toward new station locations, although younger individuals no longer appear to prefer residing around retrofit stations. As in the anticipatory model, African Americans do not appear to be particularly or differentially motivated by the location of either type of light rail stations.

As in the discussion of the anticipatory model, the results in Table 10 are overestimates of any observed impact: while the same retrofit stations are included in the anticipatory and contemporaneous models, there are fewer new stations included in the contemporaneous model, since the contemporaneous model only accounts for stations that were operational during the study period. Of the fifteen tracts with a positive percentage of residential area within a ¼ mile of the nine new stations included in the contemporaneous model, the average residential area within a ¼ mile of a new station is 10 percent, while the minimum and maximum percentages are 1 percent and 34 percent, respectively.

The growth of population and housing density around retrofit stations is significantly lessened in the contemporaneous regressions. Δ *Station Operational X Retro X Qtr-Mile* in Table 10 indicates a tract with 100 percent of residential area within a ¼ mile of a retrofit station would experience an increase of 118 residents per square mile and 124 housing units per square mile during 2010, the system's first full year of operation. When compared to the magnitude of Δ *Anticipatory X Retro X Qtr-Mile* of 1,524 and 1,076 in the population density and housing unit density regressions in Table 9, respectively, Δ *Station Operational X Retro X Qtr-Mile* in Table 10 indicates that only 7.7 percent and 11.5 percent of the total growth in population density and housing unit density that occurred within a ¼ mile of retrofit stations during the system's construction phase and first year of operation took place during the system's first year of operation. However, since the average amount of residential area within a ¼ mile of a retrofit station is 49 percent amongst the four tracts with any residential area within a ¼ mile of a retrofit station, the expected change in population density and housing unit density is 58 residents per square mile and 61 housing units per square mile in 2010.

Δ *Station Operational X New X Qtr-Mile* in Table 10 indicates a tract with 100 percent of residential area within a ¼ mile of a new station would experience a *decrease* in population density of 147 residents per square mile and an increase in housing density of 36 units per square mile. Since the average percentage of residential area within a ¼ mile of the nine new stations of all tracts with any residential area within a ¼ mile of a new station is only 10 percent, this implies that the potential observed impact is likely a decrease of 15 residents and an increase of 4 housing units. Although the directional effect of the system around new stations reverses within the contemporaneous specification in regards to the change in population density (discussed in more detail below), the vast majority of the growth in housing density occurred prior to the new stations' operation: Δ *Anticipatory X New X Qtr-Mile* in Table 9 predicts an increase in housing unit density of 730 over the construction phase and through the system's first year of operation, indicating the predicted increase of 36 units during the system's first year of operation in Table 10 only accounts for 4.9 percent of the total growth in housing units that may be attributable to the light rail. The measured impact of the two station types is consistent once the temporal operation of the toll is controlled for (Table 31 in the Appendix). *Toll Operational* in Table 31 is not associated with any economically significant impacts on the four dependent variables. Table 32 in the Appendix displays results from regressions using the log of total population and total housing as the dependent variable. The percent changes in population and housing density associated with the light rail during the system's first year of operation are not statistically or economically significant for either station type.

The light rail's reversal of directional impact on population density surrounding new stations in Table 10 may depict the cyclicality of the construction cycle which, again, is likely a function of the preexisting urban form inherent to the two station types. When this decrease in population is considered in tandem with the minimal increase of 36 housing units surrounding new stations within the system's first year of operation, one may reach the conclusion that the decline in population reflects a displacement of residents due to the negligible number of housing units added. In order to make way for the construction sites required to build entirely new stations and lay miles of track on city streets, greater numbers of buildings may have been needed to be demolished, displacing residents in the process. Another explanation for the reversal of the direction of the effect of the light rail system on population density surrounding new stations may be that population density adjusted in a different manner surrounding the nine new stations within the contemporaneous model relative to the fifteen new stations within the anticipatory model. This reversal of direction in the impact of the light rail on housing density given the change in model specification suggests that housing unit density is very sensitive to the estimation procedure, and discretion should be exercised when seeking to extrapolate from the coefficients. These minute changes in population and housing density induced by the light rail in the contemporaneous model may suggest the estimated effect of the light rail in the anticipatory specification may be the accumulation of an inwards migration to the area prior to the system's operation and suggest that households do, indeed, plan their locational decisions years in advance.

The contemporaneous specification suggests that, within the first year of the light rail's operation, the average age of residents within a ¼ mile of new stations increased relative to the rest of the study area, whereas there was no discernible change in the average age of residents within a ¼ mile of retrofit stations. Both the anticipatory and contemporaneous model specifications find an increase in the average age around new stations induced by the light rail, although the magnitude is larger in the anticipatory model. Table 10 shows the average age increased by approximately eleven months around new stations during the system's first year of operation, whereas the anticipatory model suggests the average age increased by approximately sixteen months during the stations' construction and through the system's first year of operation. The concurrence of the effect of new stations on the average age across both specifications suggests that older individuals do, indeed, appreciate proximity to new stations. However, the larger magnitude of the result in the anticipatory model suggests that the subset of individuals relocating to within a ¼ mile of new stations prior to the first year of system operation was older than the subset of individuals relocating to within a ¼ mile of new stations solely in the system's first year of operation. By 2010, new stations were still attracting older individuals, but the disparity in age between new stations and the rest of the study area had decreased. The negative impact of retrofit stations on age in the anticipatory model relative to the lack of an effect in the contemporaneous model may indicate that younger individuals *do* value proximity to retrofit stations, such that they relocated to take advantage of these locations prior to the system's implementation, as seen in Table 9. Thus, once the system was operational, the majority of younger individuals who would value proximity to retrofit stations had already relocated.

Table 34 in the Appendix displays results of the light rail system during its first year of operation on the prevalence of young and educated residents within a ¼ mile of stations included within the contemporaneous model. Although there was no significant change in the percentage of young residents within a ¼ mile of retrofit stations, the prevalence of young residents within a ¼ mile of new stations decreased by 4 percent, coinciding with the increase in the average age during the system's first year of operation, as in Table 10. The percentage of residents with at least a college degree decreased by 2 percent within a ¼ mile of retrofit stations and increased by 5 percent within a ¼ mile of new stations.

As in Table 9, African Americans do not appear to be either motivated or dissuaded to live in locations with easy access to the light rail. The lack of either a positive or negative impact from the light rail on the prevalence of African Americans for both station types is somewhat surprising since African Americans are more likely to utilize public transit (Bollinger and Ihlanfeldt, 1997). However, given that the increase in the price of housing units within both a ¼ mile and a ¼ mile to a ½ mile of stations[14] was more than double the increase in the price of housing units within the study area, less affluent African Americans may have found themselves displaced. Thus, the potential positive impacts from the light rail on the prevalence of African American communities within a ¼ mile of stations may be greatly mitigated by this process of rent capitalization, resulting in a neutral impact of the light rail on the prevalence of African Americans.

Regressions using a ½ mile proximity measurement for both model specifications are available in Table 27 and Table 28 in the Appendix. When using a ½ mile measurement of station proximity, the anticipatory model predicts *a decrease* of 1,974 residents and a gain of 634 housing units per square mile in tracts with 100 percent of residential area within a ½ mile of a retrofit station and an increase of 80 residents per square mile and a loss of eighteen housing units in a tract with 100 percent of resident area within a ½ mile of a new station (Table 27). Of the thirteen tracts with any residential area within a ½ mile of a

[14] See Table 5 and discussion within *Section VI - Summary Statistics*.

retrofit station, the mean amount of residential area within a ½ mile of a retrofit station is 45 percent, and of the thirty tracts with any residential area within a ½ mile of the fifteen new stations included within the anticipatory model, the mean amount of residential area within a ½ mile of a new station is 31 percent. Applying these averages to the results in Table 27 indicates the average tract with any residential area within a ½ mile of a retrofit station may have experienced a decrease in population of 888 and an increase of 285 housing units from 2004 through 2010, and the average tract with any residential area within a ½ mile of a new station may have experienced an increase in population of 25 residents and a loss of six housing units. Additionally, the prevalence of African Americans decreases by a statistically significant 1 percent within a ½ mile of stations included within the anticipatory specification. Figure 20 in the Appendix displays annual total population within a ½ mile of all anticipatory stations.

Table 28 presents the results of the contemporaneous model using a ½ mile proximity measurement. A tract with 100 percent of residential area within a ½ mile of a retrofit station would experience a decrease of 147 residents and an increase of 106 housing units per square mile, and a tract with 100 percent of residential area within a ½ mile of a new station would experience a decrease in population of 23 residents and a gain of 10 housing units per square mile (Table 28), during the system's first year of operation. Since the average tract with any residential area within a ½ mile of a retrofit station has 45 percent of residential area within a ½ mile of a retrofit station, the average tract with any residential area within a ½ mile of a retrofit station may have experienced an increase of 66 residents and 48 housing units. Of the twenty tracts with any residential area within a ½ mile of the nine new stations in the contemporaneous model, the mean amount of residential area within a ½ mile of new station is 36 percent. This implies the average tract within a ½ mile of a new station may have experienced an increase of 8 residents and 4 housing units during the system's first full year of operation. Figure 21 in the Appendix displays the annual trend in total population within a ½ mile of all stations included within the contemporaneous model.

VII.C. Toll Estimation

Individuals appear to perceive the toll as a benefit, likely due to its congestion lowering qualities, as population density has increased within the two sets of boundaries defining proximity to the tolled corridor. When proximity to the SR-520 bridge is defined as a tract with any percentage of its residential area existing within two miles of the SR-520 termini (Comparison Group I proximity designation), the toll is associated with an increase in population density of 18 to 70 individuals per square mile across the anticipatory and contemporaneous model specifications. When proximity to the bridge is defined as a tract with any portion of its area within 1.5 miles of a ramp within five miles of the SR-520 bridge termini (Comparison Group II proximity designation), the toll is associated with an increase in population density of 91 to 107 individuals per square mile across model specification. However, due to the low initial population density within two miles of the SR-520 termini, the relative change in population is larger within the Comparison Group I boundary than the Comparison Group II boundary. There is no discernible impact from the toll on housing density, the prevalence of African Americans or the average age in either model specification or for either Comparison Group. There is also no measurable impact from the toll when proximity to the bridge is measured as a tract's centroid distance to the bridge. Additionally, controlling for the temporal operation of the light rail does not impact the results.

VII.C.I. Toll Estimation, Comparison Group I

Table 11 displays the results of the anticipatory model specification using the Comparison Group I definition of proximity to the SR-520. Recall Comparison Group I accounts for a weighted impact from the toll in all tracts with any portion of residential area within two miles of the SR-520 termini. *Toll Anticipatory Wgt. X Proximity 520* in Table 11 indicates a tract with 100 percent of residential area within two miles of the SR-520 termini would experience an increase in population density of 70 residents per square mile upon the announcement of the toll through the end of the panel (2009 through 2014). This result is statistically significant at the 90th percent confidence level. Column 1 in Table 38 in the Appendix displays results from a log transformation of total population: *Toll Anticipatory Wgt. X Proximity 520* in Table 38 indicates total population may increase by 1 percent for a tract with 100 percent of residential area within two miles of the SR-520 bridge termini over the same period. As in the light rail estimation, the results in Table 11 are overestimates of any observable impact: amongst the 26 tracts with a positive percentage of residential area within two miles of the SR-520 bridge termini, the average percentage of residential area within two miles of the SR-520 bridge termini is 66 percent while the minimum and maximum percentages are 0.1 and 100, respectively. This implies the average tract with any portion of residential area within two miles of the SR-520 termini may have experienced an increase of 46 residents from 2009 through 2014.

Table 11 - Effect of Toll on Population Characteristics, Anticipatory Model – Comparison Group I Proximity Measurement

	Dependent Variable			
	ΔPopulation Density	ΔHousing Density	ΔLag Black	ΔAge
Independent Variable				
Distance to CBD	-0.417	1.286	4.50e-05	0.0153***
	(2.434)	(1.359)	(3.85e-05)	(0.00255)
Percent Commuting to CBD	76.01	296.0***	-0.00581**	0.101
	(170.5)	(96.43)	(0.00253)	(0.172)
Eastside	18.70	18.85**	-5.55e-06	-0.0278
	(17.08)	(9.535)	(0.000279)	(0.0184)
Δ Lag Black	4,834***	510.2		-1.129
	(1,517)	(964.5)		(1.424)
Δ Lag Income	0.00211**	0.00115**	8.19e-09	2.00e-06**
	(0.000867)	(0.000574)	(9.55e-09)	(7.92e-07)
Δ Lag Unemployment	170.9	-29.23	-0.000726	0.255
	(292.3)	(193.9)	(0.00321)	(0.267)
Δ Lag Poverty	-450.8**	-361.2***	0.00423**	-0.452***
	(185.9)	(123.4)	(0.00204)	(0.170)
Δ Age	-173.1***	-84.51***	-8.24e-05	
	(19.04)	(12.30)	(0.000217)	
Δ Education	180.1	102.2	-0.00336**	0.0316
	(147.2)	(97.48)	(0.00162)	(0.135)
Δ Commute Length	94.49	-22.33	-0.000200	-0.244**
	(126.7)	(84.10)	(0.00139)	(0.116)
Δ Pct. Utilizing Public Transit	94.88	93.01	0.00338	-0.0419
	(190.4)	(126.4)	(0.00209)	(0.174)
Initial Value	0.0144***	0.0136***	0.00534***	0.00614***
	(0.00125)	(0.000994)	(0.00133)	(0.00175)
Pct. Residential	-96.33***	-65.84***	-6.90e-05	-0.0398**
	(19.10)	(10.56)	(0.000300)	(0.0202)
Anticipatory Weight	28.70***	4.346	-0.0004***	0.0432***
	(7.993)	(5.326)	(8.71e-05)	(0.00724)
Proximity 520	0.539	-7.432	-0.0027***	-0.0896**
	(36.69)	(21.74)	(0.000532)	(0.0374)
Proximity I-90	-25.85	-15.17	-0.0031***	0.0353
	(28.07)	(15.82)	(0.000452)	(0.0294)
Anticipatory Weight X Proximity 520	69.83*	-9.482	0.00326***	0.271***
	(39.96)	(26.62)	(0.000433)	(0.0361)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The second column in Table 11 displays results from a regression of housing unit density: *Toll Anticipatory Wgt. X Proximity 520* indicates that a tract with 100 percent of its residential area within two miles of the SR-520 termini would experience an economically and statistically insignificant decrease in housing unit density of 10 units per square mile between 2009 and 2014. Thus, the current housing stock was sufficient for the minor increase in population density within the two-mile boundary around the SR-520 bridge termini displayed in the first column. However, log regression results in Table 38 indicate the same tracts would experience a 0.5 percent *increase* in housing units. The opposing directional impacts of the toll on a level of housing unit density versus a log of total housing units likely reflects noise in the model.

The households that are motivated to relocate closer to the SR-520 bridge termini upon the implementation of the toll may be revealing their preference to pay a fee to avoid congestion. The net gain in population of 70 individuals per square mile within the toll impact area could be a result of high-income households relocating towards the SR-520 to take advantage of the redistribution of congestion away from the tolled corridor. The lull in the building of additional housing units may reflect developers' hesitation to erect additional multi-family units within the two-mile boundary since the area may no longer be desirable for lower income renters due to the cost associated with the toll.

The criterion defining a tract's spatial relationship with either bridge are not economically or statistically significant as solitary terms. However, *Proximity I-90* and *Proximity 520* in Table 11 provide both a semblance of understanding as to the distribution of population related to the lake and additional context for the slight population shifting that occurred after the toll was implemented. According to *Proximity I-90*, a tract with 100 percent of its residential area within two miles of the I-90 termini had approximately 26 fewer residents per square mile relative to tracts within the rest of the study area over the course of the panel. This is likely a result of the many spatial constraints surrounding the I-90 termini, such as parks and freeway interchanges. The population distribution within two miles of the SR-520 bridge termini is nearly identical across the panel, with *Proximity 520* indicating a tract with 100 percent of its residential area within two miles of the SR-520 bridge termini had approximately 1 additional person per square mile relative to the rest of the study area. However, the similar population density between the entire study area and the vicinity within two miles of the SR-520 termini stands in stark contrast with the gradual increase of 70 individuals per square mile within two miles of the SR-520 bridge termini upon the announcement of the toll through the end of the panel.

Additional regression variations of the anticipatory model using the Comparison Group I definition of bridge proximity are available in the Appendix. Table 35 displays the effect from the toll when bridge proximity is measured as a continuous variable reflecting distance from the tolled corridor. *Anticipatory Weight X Distance to 520* in Table 35 indicates a one mile increase in distance to the SR-520 termini is associated with 10 fewer residents per square mile and one fewer housing unit per square mile once the toll was announced in 2009. This finding is consistent with the increase in population density within the two-mile boundary of the SR-520 bridge termini (*Proximity 520* in Table 11) upon the implementation of the toll discussed above, suggesting that living within a certain proximity of the lake became more desirable once the toll was implemented. The inclusion of a dummy variable controlling for the operational status of the light rail system does not affect the impact from the toll on population or housing density (see Table 37), although the operation of the light rail is associated with an increase in 23 housing units per square mile across the entire study area (*LR Operational* in Table 37).

Table 11 also displays the toll's impact on the prevalence of African Americans and the average age. The prevalence of African Americans and the average age of individuals exhibited very slight increases within two miles of the SR-520 bridge termini upon the announcement of the toll. Although neither result is economically significant, both are highly statistically significant. *Anticipatory Wgt. X Proximity 520* predicts a tract with 100 percent of its residential area within two miles of the SR-520 bridge termini would experience a 0.3 percent increase in the prevalence of African Americans and an increase in the average age of approximately three months. The lack of an economically significant impact from the toll on race and age within Table 11 may be a function of the high-incomes required to establish a household in the area. The pre-established residents within the two-mile SR-520 termini boundary have self-identified as having high incomes and are predominantly white. Not surprisingly, residents who are willing and able to relocate to the area to take advantage of the decreased congestion are likely to be similar in demographic composition to the preexisting residents. Table 35 in the Appendix indicates there was no change in the location of African American households or the average age upon the implementation of the toll when measuring proximity to the bridge termini using distance. Additionally, controlling for the operation of the light rail does not affect the impact from the toll on the prevalence of African Americans and the average age within the toll impact area (see Table 37 in the Appendix).

Regression results generated using the contemporaneous toll model and the spatial criterion defined by Comparison Group I are presented in Table 12. Once the impact from the toll is only accounted for in 2012 and later, one generally observes a decrease in the magnitude of the variable of interest, *Toll Operational X Distance to SR-520,* relative to its anticipatory counterpart in Table 11*, Anticipatory Weight X Proximity 520*, implying individuals anticipated the toll's operation and began relocating to within two miles of the SR-520 termini prior to its operation. However, relative to the percentage of individuals

Table 12 - Effect of Toll on Population Characteristics, Contemporaneous Model – Comparison Group I Proximity Measurement

	Dependent Variable			
	ΔPopulation Density	ΔHousing Density	ΔLag Black	ΔAge
Independent Variable				
Distance to CBD	-0.670	1.267	4.70e-05	0.0153***
	(2.435)	(1.359)	(3.85e-05)	(0.00255)
Percent Commuting to CBD	70.29	295.0***	-0.00578**	0.0958
	(170.5)	(96.42)	(0.00253)	(0.172)
Eastside	18.92	18.86**	-6.75e-06	-0.0278
	(17.08)	(9.535)	(0.000279)	(0.0184)
Δ Lag Black	5,113***	491.7		-1.969
	(1,519)	(965.8)		(1.438)
Δ Lag Income	0.00225***	0.00115**	7.98e-09	2.2e-06***
	(0.000867)	(0.000574)	(9.53e-09)	(8.00e-07)
Δ Lag Unemployment	168.5	-15.56	-0.000916	0.408
	(292.3)	(194.0)	(0.00321)	(0.270)
Δ Lag Poverty	-441.6**	-357.9***	0.00453**	-0.350**
	(186.0)	(123.4)	(0.00204)	(0.172)
Δ Age	-156.1***	-83.14***	-0.000206	
	(18.87)	(12.20)	(0.000215)	
Δ Education	193.2	109.9	-0.00336**	0.120
	(147.1)	(97.42)	(0.00162)	(0.136)
Δ Commute Length	81.77	-11.11	2.52e-05	-0.0846
	(127.0)	(84.28)	(0.00139)	(0.117)
Δ Pct. Utilizing Public Transit	99.30	94.56	0.00335	-0.0365
	(190.4)	(126.4)	(0.00209)	(0.176)
Initial Value	0.0145***	0.0136***	0.00533***	0.00611***
	(0.00125)	(0.000994)	(0.00133)	(0.00175)
Pct. Residential	-95.54***	-65.80***	-7.57e-05	-0.0403**
	(19.11)	(10.56)	(0.000300)	(0.0201)
Toll Operational	29.76***	-0.954	-0.0004***	-0.0267***
	(7.207)	(4.804)	(7.84e-05)	(0.00662)
Proximity 520	29.12	-7.448	-0.0024***	-0.0341
	(32.99)	(18.92)	(0.000502)	(0.0345)
Proximity I-90	-25.72	-15.23	-0.0031***	0.0334
	(28.09)	(15.82)	(0.000451)	(0.0294)
Toll Operational X Proximity 520	18.34	-14.14	0.00314***	0.238***
	(36.06)	(24.03)	(0.000390)	(0.0330)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

who anticipated the light rail's operation and relocated prior to the system's commencement, a smaller percentage of the total residents who chose to relocate due to the toll had done so by the time the toll was operational: of the estimated increase in population density of 70 individuals from the announcement of the toll through the end of the panel (Table 11), 26 percent (18 residents) of this increase is estimated to occur once the system was operational in 2012 through the end of the panel (Table 12). The direction of the effect of the toll remains constant for each dependent variable between the anticipatory and contemporaneous specifications. Log regression results of total population and total housing are available in Table 39 in the Appendix.

The constant directional effect of the toll on the variables of interest between the anticipatory and contemporaneous model serves as a robustness check as to the credibility of the results produced. Population density, the prevalence of African Americans and the average age all increase in tracts with 100 percent of residential area within two miles of the SR-520 termini upon the operation of the toll through the end of the panel, although the estimated effects in Table 12 are slightly smaller than the results produced in the anticipatory model (Table 11). *Toll Operational X Distance to SR-520* indicates a tract with 100 percent of its residential area within two miles of the SR-520's termini would experience an increase in population density of 18 individuals per square mile, the prevalence of African American would increase by a highly statistically significant 0.3 percent and the average age would increase by a highly statistically significant three months. This mitigating effect produced from restraining the time in which the toll is accounted for suggests the results produced within the anticipatory model simply reflect an aggregation of the toll's impact across a longer time frame, as in the light rail estimation. The toll’s small negative impact on housing density increases slightly in magnitude when only accounting for an effect from 2012 through 2014, increasing from a loss of 10 units per square mile in Table 11 to a loss of 14 units per square mile in Table 12. This increase in the magnitude of the loss in housing units, although the resulting estimate remains negligible, may suggest a very slight positive impact from the anticipation of the toll bolstering the variable of interest between 2009 through 2011 in Table 11. However, the insignificant degree of the decrease in housing units across both model specifications holds no economic significance.

The magnitude of the variable of interest does not exhibit as much variation across Comparison Group I's anticipatory and contemporaneous models as is observed in the variation of Δ *Station Operational X Retro X Qtr-Mile* and Δ *Station Operational X New X Qtr-Mile* across the anticipatory and contemporaneous models. This may suggest that much of the dynamics of population shifting occurred after the toll became operational, therefore lending some credence to the chosen modeling technique: since there is no benefit to relocating towards or away from the SR-520 termini prior to the toll becoming operational, only the most mobile or motivated households will relocate before its unveiling. However, within the light rail estimation, one witnesses the vast majority of relocations occurring *prior* to the system's operation, indicating households that value proximity to the light rail will relocate to ensure access to its services prior to its commencement of services.

VII.C.II. Toll Estimation, Comparison Group II

The toll has a larger absolute impact on the distribution of population and housing when proximity to the SR-520 termini is defined as tracts with any portion of area within 1.5 miles of a ramp within five miles of the bridge termini (Comparison Group II). Table 13 displays results from the proximity specification using Comparison Group II criterion within the anticipatory model. *Anticipatory Weight X Proximity 520* indicates a tract with 100 percent of its residential area within 1.5 miles of a ramp within five miles of the SR-520 bridge termini would experience a highly statistically significant increase in population

Table 13 - Effect of Toll on Population Characteristics, Anticipatory Model – Comparison Group II Proximity Measurement

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Lag Black	Δ Age
Independent Variable				
Δ Lag Black	3,212**	371.3		-5.490***
	(1,537)	(975.4)		(1.415)
Δ Lag Income	0.00203**	0.00115**	5.98e-09	1.83e-06**
	(0.000862)	(0.000575)	(9.26e-09)	(7.72e-07)
Δ Lag Unemployment	202.2	-29.57	2.48e-05	0.315
	(290.6)	(193.9)	(0.00311)	(0.260)
Δ Lag Poverty	-449.3**	-361.7***	0.00357*	-0.468***
	(184.7)	(123.2)	(0.00198)	(0.165)
Δ Age	-198.5***	-92.31***	-0.0007***	
	(19.41)	(12.59)	(0.000217)	
Δ Education	160.2	102.6	-0.00319**	0.0231
	(145.9)	(97.09)	(0.00157)	(0.131)
Δ Commute Length	92.88	-20.49	-0.000354	-0.252**
	(126.0)	(84.08)	(0.00135)	(0.113)
Δ Pct. Utilizing Public Transit	58.82	76.48	0.00255	-0.0833
	(189.3)	(126.3)	(0.00203)	(0.169)
Initial Value	0.0139***	0.0135***	0.00312**	0.00508***
	(0.00128)	(0.000999)	(0.00138)	(0.00174)
Pct. Residential	-90.33***	-61.50***	2.63e-05	-0.0362*
	(19.04)	(10.46)	(0.000314)	(0.0199)
Distance to CBD	3.446	3.416**	3.58e-05	0.0127***
	(2.730)	(1.519)	(4.51e-05)	(0.00283)
Percent Commuting to CBD	89.30	326.1***	-0.00618**	0.174
	(167.8)	(94.52)	(0.00263)	(0.169)
Eastside	7.399	15.69	-0.000130	-0.00469
	(17.96)	(9.891)	(0.000299)	(0.0193)
Anticipatory Weight	-3.404	-2.358	-0.0012***	-0.0229***
	(9.774)	(6.544)	(0.000102)	(0.00872)
Proximity 520	-54.35***	-18.55	-0.0019***	-0.189***
	(20.57)	(11.90)	(0.000318)	(0.0203)
Proximity I-90	53.29***	28.31***	-0.0006**	0.0327*
	(17.72)	(9.804)	(0.000295)	(0.0185)
Anticipatory Weight X Proximity 520	107.0***	19.49	0.00297***	0.229***
	(18.03)	(12.04)	(0.000186)	(0.0156)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

density of 107 residents per square mile and an addition of twenty housing units per square mile. Although the absolute magnitude of the toll's impact is larger using the Comparison Group II criterion, the change in population and housing figures relative to the initial base numbers are not: regression results on the log of total population and total housing indicate the same tracts would experience a 0.8 percent increase and a 0.2 percent increase in total population and total housing (see Table 42 in the Appendix), respectively. As in the prior models, the results in Table 13 are an overestimate of any observed changes due to many tracts not existing entirely within the Comparison Group II criterion. However, the results pertaining to the Comparison Group II proximity measurement are less inflated relative to estimates for both the light rail and the toll within the Comparison Group I proximity measurement. For all tracts with a positive value corresponding to the Comparison Group II criterion, the average percentage of residential area within 1.5 miles of a ramp within five miles of a bridge is 80 percent while the maximum and minimum values are 1 percent and 100 percent, respectively. This indicates the average tract with any portion of residential area within 1.5 mile of an exit within five miles of the SR-520 termini may have experienced an increase in population of 86 residents from 2009 through 2014. As in the Comparison Group I specifications, controlling for the operation of the light rail does not impact the magnitude of the coefficient of interest (Table 40 in the Appendix).

The larger increase in population density along the SR-520 ramps relative to the two-mile boundary around the SR-520 bridge termini may have two implications. The first implication is that income is only a minor factor in an individual's decision of whether to use the tolled bridge. Only very high-income households are able to locate within two miles of the SR-520 termini, but, even amongst individuals who cannot afford to live within the Comparison Group I boundaries, households still exhibited a preference to relocate to an area in which they have easy access to the SR-520 bridge once the toll was operational. The increased public transit availability crossing the lake also eliminates the financial impact of the toll on low-income households, creating a benefit associated with the toll beyond the reduced congestion and potentially reversing the deterrence of the toll on lower income households.

The second implication is that individuals are locating around the SR-520 corridor independently of the toll. The Comparison Group II criterion may not effectively delineate a population that is directly responding to the transit intervention and the model is, thus, quantifying some extraneous influence. The wide swath of the population contained within the Comparison Group II boundary captures households that have easy access to the I-90 bridge and controls for the ability of households circumnavigating the lake to the South (see Figure 8 in *Section V*). Households within Comparison Group II are also more likely to find it unnecessary to cross the lake at all if one assumes that households' locational decisions are a function of ensuring proximity to work, school and activities.

Proximity I-90 and *Proximity 520* in Table 13 provide context as to the distribution of the population relative to the two major freeways that traverse the lake. Across the duration of the panel and relative to the entire 25-km study area, households appear to prefer residing within 1.5 miles of a ramp within five miles of I-90 ramps and appear to avoid locating in areas relative to the same spatial relationship applicable to the SR-520. *Proximity I-90* indicates there are 53 more residents and 28 more housing units within the Comparison Group II designation applicable to the I-90, whereas *Proximity 520* indicates there are 54 fewer residents and nineteen fewer housing units within the same criterion applicable to the SR-520. The lower population density within the Comparison Group II boundaries applicable to the SR-520 across the entire panel is sharply divergent from the growth in population of 107 displayed by *Anticipatory Weight X Proximity 520* upon the operation of the toll. This may suggest that the toll itself *is* the catalyst for the increase in population density, potentially indicating the toll could provide a stabilizing influence on the distribution of the growth in population relative to the region's two major east to west corridors.

Columns 3 and 4 in Table 13 display the toll's impact on the prevalence of African Americans and the average age from the anticipatory model using the Comparison Group II criterion. The model predicts that a tract with 100 percent of its residential area within 1.5 miles of a rap within five miles of the SR-520 termini would experience a 0.3 percent increase in the prevalence of African Americans and a three month increase in the average age. Both estimates are very similar to the estimates produced in the anticipatory model using the Comparison Group I criterion, indicating the toll does not appear to differently impact households' locational decisions by race or age based on the spatial definition of bridge proximity used. Although the toll could be negatively impacting the ability of low-income households to traverse the bridge, the results in Table 13 suggest that equity concerns regarding the toll's impact on the locational decisions of low-income households may be misguided. As discussed above, the expansion of public transit availability across the lake may make the toll's operation irrelevant for low income households within the Comparison Group II boundaries. Table 40 in the Appendix displays results of the anticipatory model using the Comparison Group II definition of bridge proximity while also controlling for the impact of the light rail's operation. The operation of the light rail system does not alter the toll's impact on race and age.

Table 14 displays the estimates from the contemporaneous model using the Comparison Group II criterion. The magnitude of the estimates of *Proximity 520 X Toll Operational*

Table 14 - Effect of Toll on Population Characteristics, Contemporaneous Model – Comparison Group II Proximity Measurement

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Lag Black	Δ Age
Independent Variable				
Distance to CBD	3.191	3.388**	3.58e-05	0.0127***
	(2.730)	(1.518)	(4.50e-05)	(0.00283)
Percent Commuting to CBD	79.25	324.2***	-0.00619**	0.171
	(167.9)	(94.52)	(0.00263)	(0.169)
Eastside	7.374	15.68	-0.000126	-0.00463
	(17.96)	(9.892)	(0.000299)	(0.0193)
Δ Lag Black	3,193**	347.7		-5.653***
	(1,548)	(981.5)		(1.454)
Δ Lag Income	0.00212**	0.00115**	3.53e-09	1.93e-06**
	(0.000863)	(0.000575)	(9.18e-09)	(7.91e-07)
Δ Lag Unemployment	153.6	-24.48	-0.00128	0.396
	(290.6)	(193.9)	(0.00309)	(0.266)
Δ Lag Poverty	-406.4**	-350.8***	0.00427**	-0.362**
	(184.6)	(123.2)	(0.00196)	(0.169)
Δ Age	-176.7***	-89.55***	-0.00070***	
	(19.02)	(12.34)	(0.000210)	
Δ Education	161.3	110.0	-0.00327**	0.114
	(145.9)	(97.08)	(0.00155)	(0.134)
Δ Commute Length	111.5	-3.027	0.000715	-0.0538
	(126.3)	(84.32)	(0.00134)	(0.116)
Δ Pct. Utilizing Public Transit	18.94	71.75	0.00119	-0.130
	(189.8)	(126.6)	(0.00201)	(0.174)
Initial Value	0.0140***	0.0135***	0.00311**	0.00507***
	(0.00128)	(0.000999)	(0.00138)	(0.00174)
Pct. Residential	-89.57***	-61.42***	2.33e-05	-0.0368*
	(19.05)	(10.46)	(0.000314)	(0.0199)
Toll Operational	-1.124	-6.904	-0.00124***	-0.0726***
	(8.982)	(6.008)	(9.26e-05)	(0.00812)
Proximity 520	-29.64	-13.58	-0.00141***	-0.129***
	(19.14)	(10.78)	(0.000309)	(0.0193)
Proximity I-90	52.61***	28.22***	-0.000596**	0.0329*
	(17.73)	(9.805)	(0.000295)	(0.0185)
Proximity 520 X Toll Operational	90.57***	14.98	0.00289***	0.165***
	(16.22)	(10.83)	(0.000164)	(0.0146)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

across all dependent variables is smaller within the contemporaneous model than the magnitude of the corresponding variable of interest within the anticipatory model, *Proximity 520 X Anticipatory Weight*. The model predicts a tract with 100 percent of its residential area within 1.5 miles of a ramp within five miles of the SR-520 termini would experience an increase in population density of 91 residents per square mile, an increase of fifteen housing units per square mile, an increase in the prevalence of African Americans by 0.3 percent and an increase in the average age of two months.

The difference in magnitude between the estimated coefficients within the anticipatory and contemporaneous models varies between the light rail and toll models and also between the definitions of bridge proximity used within the toll models. Within the light rail models, the estimates of the station variables produced by the anticipatory model are orders of magnitude larger than those within the contemporaneous model, suggesting individuals relocated preemptively to ensure access to the light rail. The difference in the estimated coefficients between the anticipatory and contemporaneous models is much larger using the Comparison Group I criterion than the Comparison Group II criterion, conveying that households were adjusting their locations after the toll was operational within the Comparison Group II boundaries, but not before as in Comparison Group I.

Since vicinities within the Comparison Group I boundaries experienced a larger relative increase in population *and* this increase aligns with a preemptive positioning to realize a maximum benefit from the redistribution of traffic related to the toll, one may deduce that the Comparison Group I definition of proximity allows for a better capturing of the population that may be responsive to the toll than the Comparison Group II definition of proximity. Households able to relocate within the Comparison Group I boundaries may be self-identifying as individuals who must cross the bridge frequently, therefore valuing increased access and expedited travel more than households within the Comparison Group II boundaries. Therefore, the potential time savings and realized benefit from the toll may be larger for households within the Comparison Group I boundaries than the Comparison Group II boundaries.

VII.D. Combined Estimation

Results from the combined anticipatory model estimation of the light rail and toll using both Comparison Group I and Comparison Group II's definitions of proximity are presented in Table 15 and Table 16. The estimated coefficients related to the toll are generally similar to their previous counterparts in the solitary models, whereas the estimated coefficients related to the two station variables exhibit a great deal of variation across the solitary and combined models. The following discussion primarily focuses on estimates that differ from the solitary models.

Table 15 displays the estimated coefficients from the combined anticipatory model using the Comparison Group I definition of SR-520 bridge proximity. Once the toll is accounted for on a spatial dimension, the impact from the light rail on population density increases from 2,571 to 2,797 residents per square mile and decreases from 1,657 to 1,524 residents per square mile for tracts with 100 percent of residential area within a ¼ mile of new and retrofit stations, respectively. Given the average amount of residential area within a ¼ mile of a station for each station type, the potential observed increase in population density is 252 around new stations and 747 around retrofit stations from 2004 through 2010.Once the light rail’s impact area is accounted for, the toll’s effect on population density within the

Table 15 - Effect of the Light Rail and Toll on Population and Demographics, Combined Anticipatory Model, Comparison Group I Measurement

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Lag Black	Δ Age
Independent Variable				
Δ Lag Black	5,277***	568.8		-0.613
	(1,550)	(997.3)		(1.430)
Δ Age	-177.3***	-87.62***	0.000170	
	(19.26)	(12.54)	(0.000221)	
Δ Education	164.7	94.18	-0.00102	0.0204
	(147.4)	(97.75)	(0.00167)	(0.135)
Δ Lag income	0.00225***	0.00126**	-6.39e-10	1.91e-06**
	(0.000869)	(0.000576)	(9.85e-09)	(7.92e-07)
Δ Lag unemployment	141.5	-47.27	-0.00495	0.267
	(292.5)	(194.3)	(0.00331)	(0.267)
Δ Lag poverty	-444.6**	-356.6***	-0.000281	-0.456***
	(186.0)	(123.6)	(0.00211)	(0.170)
Δ Commute Length	79.20	-36.38	0.00226	-0.230**
	(127.0)	(84.36)	(0.00144)	(0.116)
Δ Pct. Utilizing Public Transit	92.54	101.2	-0.000917	-0.0638
	(190.8)	(126.7)	(0.00216)	(0.174)
Δ Home Price	2.57e-05**	1.87e-05**	9.40e-11	-1.12e-08
	(1.10e-05)	(7.32e-06)	(1.25e-10)	(1.00e-08)
Initial Value	0.00980***	0.0105***	0.00458***	0.00586***
	(0.00147)	(0.00126)	(0.00115)	(0.00177)
Distance to CBD	-0.641	1.548	7.03e-05**	0.0139***
	(2.668)	(1.523)	(3.36e-05)	(0.00259)
Distance to Freeway	-0.661	-3.040	-0.000359***	0.0178***
	(6.292)	(3.578)	(7.87e-05)	(0.00610)
Pct. Commuting to CBD	248.6	429.7***	-0.00423*	0.125
	(184.6)	(105.7)	(0.00217)	(0.171)
Pct. Residential	-85.76***	-70.46***	-0.000177	-0.0369*
	(20.63)	(11.66)	(0.000258)	(0.0201)
Eastside	17.34	21.65**	-0.000119	-0.0198
	(18.43)	(10.51)	(0.000241)	(0.0184)
Toll-Weight	32.30***	6.380	-0.000312***	0.0428***
	(8.027)	(5.345)	(9.05e-05)	(0.00727)
Proximity 520	20.12	-4.075	-0.00258***	-0.0873**
	(38.67)	(23.11)	(0.000472)	(0.0373)
Proximity I90	-39.13	-24.75	-0.00248***	0.0364
	(30.19)	(17.45)	(0.000386)	(0.0291)
Toll-Weight X Proximity 520	47.17	-21.46	0.00343***	0.269***
	(40.44)	(26.91)	(0.000454)	(0.0365)
Δ Anticipatory X Retro X Qtr-Mile	1,657**	1,048**	-0.00311	-1.124*
	(731.9)	(466.4)	(0.00849)	(0.678)
Δ Anticipatory X New X Qtr-Mile	2,797**	931.2	-0.0176	1.908*
	(1,121)	(706.9)	(0.0126)	(1.002)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

two-mile radii boundaries around the SR-520 termini decreases, from 70 to 47 individuals per square mile. The actual expected increase in population density within two miles of the SR-520 termini is 37 residents per square mile from 2012 through 2014. However, the toll's impact continues to carry little economic significance due to its small magnitude.

The impact of each transit intervention on housing density varies once the alternative transit intervention is controlled for at the spatial level. In the solitary specification, a tract with 100 percent of residential area within a ¼ mile of a new station is predicted to experience an increase in housing density of 730 units from the initiation of station construction through the end of the system's first year of operation. However, once the toll is controlled for at the spatial level, the model predicts the same tract will experience an increase in housing units of 931 units per square mile. The combined model predicts a slight decrease in the addition of housing units around retrofit stations relative to the solitary light rail anticipatory model, with *Δ Anticipatory X Retro X Qtr-Mile* in Table 15 predicting an increase of 1,048 housing units in a tract with 100 percent of residential area within a ¼ mile of a retrofit station (as opposed to 1,076 in the solitary model) and maintains its high degree of statistical significance. The actual expected increase in housing units is 84 housing units for tracts within a ¼ mile of a new station and 514 housing units for tracts within a ¼ mile of retrofit station. The toll's impact on housing density within two miles of the SR-520 bridge termini remains negligible in the combined model.

The combined model specification shown in Table 15 produces coefficients of larger magnitudes for both Δ *Lag Black* and Δ *Age*. Although African American communities do not post a statistically or economically significant response to the light rail system within Table 9, their calculated response is larger once the toll is controlled for in Table 15: a tract

Table 16 - Effect of the Light Rail and Toll on Population and Demographics, Combined Anticipatory Model, Comparison Group II Measurement

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Lag Black	Δ Age
Independent Variable				
Δ Lag Black	3,773**	524.2		-4.998***
	(1,575)	(1,015)		(1.427)
Δ Age	-203.5***	-96.01***	-0.000501**	
	(19.61)	(12.82)	(0.000220)	
Δ Education	138.7	90.81	-0.000840	0.0168
	(146.1)	(97.41)	(0.00161)	(0.131)
Δ Lag income	0.00213**	0.00122**	-2.69e-09	1.78e-06**
	(0.000864)	(0.000577)	(9.54e-09)	(7.72e-07)
Δ Lag unemployment	177.0	-43.56	-0.00433	0.319
	(290.7)	(194.3)	(0.00321)	(0.260)
Δ Lag poverty	-434.9**	-351.9***	-0.000997	-0.472***
	(184.7)	(123.4)	(0.00204)	(0.165)
Δ Commute Length	83.03	-31.01	0.00212	-0.238**
	(126.2)	(84.35)	(0.00139)	(0.113)
Δ Pct. Utilizing Public Transit	51.45	82.45	-0.00187	-0.106
	(189.6)	(126.7)	(0.00209)	(0.170)
Δ Home Price	2.37e-05**	1.65e-05**	9.14e-11	-9.10e-09
	(1.09e-05)	(7.26e-06)	(1.20e-10)	(9.71e-09)
Initial Value	0.00946***	0.0107***	0.00230*	0.00502***
	(0.00147)	(0.00124)	(0.00119)	(0.00175)
Distance to CBD	4.330	4.229**	3.71e-05	0.0123***
	(2.936)	(1.669)	(3.80e-05)	(0.00283)
Distance to Freeway	4.505	-0.754	-0.000451***	0.0139**
	(6.419)	(3.646)	(8.41e-05)	(0.00622)
Pct. Commuting to CBD	229.0	446.6***	-0.00473**	0.166
	(181.4)	(103.4)	(0.00222)	(0.170)
Pct. Residential	-77.47***	-64.87***	-0.000122	-0.0324
	(20.58)	(11.57)	(0.000265)	(0.0199)
Eastside	-1.390	15.32	-0.000140	-0.00227
	(19.24)	(10.87)	(0.000252)	(0.0192)
Toll-Weight	-0.740	-1.163	-0.00117***	-0.0221**
	(9.795)	(6.561)	(0.000106)	(0.00874)
Proximity 520	-35.35	-11.96	-0.00222***	-0.180***
	(22.04)	(12.95)	(0.000281)	(0.0206)
Proximity I90	61.83***	31.94***	-0.000725***	0.0371**
	(19.23)	(10.91)	(0.000251)	(0.0187)
Toll-Weight X Proximity 520	107.0***	20.17*	0.00314***	0.227***
	(18.15)	(12.13)	(0.00193)	(0.0157)
Δ Anticipatory X Retro X Qtr-Mile	1,987***	1,084**	0.0137*	-0.126
	(729.4)	(465.9)	(0.00833)	(0.665)
Δ Anticipatory X New X Qtr-Mile	2,450**	657.5	-0.0109	1.889*
	(1,109)	(700.0)	(0.0124)	(0.979)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

with 100 percent of residential area within a ¼ mile of a new station would experience a 1.8 percent decrease in African American residents once the spatial presence of the toll is accounted for. The impact of the light rail on the prevalence of African American residents within a ¼ mile of retrofit stations remains negligible within the combined model. The impact from *Toll-Weight X Proximity 520* on the location of African American communities remains nearly identical between the solitary (Table 11) and combined model (Table 15) and, again, suggests a statistically significant 0.3 percent increase in the percentage of African Americans near the SR-520 bridge termini once the toll is announced through the end of the panel, although the minute magnitude of the coefficient makes it a trivial point.

Controlling for the toll at the tract level increases the magnitude of *Δ Anticipatory X Retro X Qtr-Mile* and *Δ Anticipatory X New X Qtr-Mile* on the average age within a tract and increases the light rail's statistical significance associated with age: the average age increases by 23 months around tracts with 100 percent of residential area within a ¼ mile of new stations (up from sixteen months in the solitary model) and decreases by thirteen months within tracts with 100 percent of residential area within a ¼ mile of retrofit stations (from twelve months in the solitary model). *Toll-Weight X Proximity 520* continues to have an inconsequential impact on the average age of three months once the spatial presence of the light rail is controlled for, although it remains highly statistically significant.

The contemporaneous combined model using the Comparison Group I definition of bridge proximity is displayed in Table 43 in the Appendix. There are no significant changes in the impact of the toll on the population and demographic variables once the light rail's spatial presence is controlled for. As in the anticipatory combined model, the changes in *Δ*

Anticipatory X New X Qtr-Mile between the solitary and combined model are much larger than the changes in *Δ Anticipatory X Retro X Qtr-Mile* between the two models. Although the fluctuations between the estimated coefficients on *Δ Anticipatory X New X Qtr-Mile* between the solitary and combined models are large in percentage terms, the small value of the resulting coefficients carries little economic significance.

The smaller difference between the new station variable across the solitary and combined models within the contemporaneous specification as opposed to the anticipatory specification is likely due to the additional stations included within the anticipatory model. Four of the fifteen new stations included within the anticipatory model[15] fall within the Comparison Group I boundary on the west side of the lake (see Figure 16 in the Appendix). There is no overlap between any of the nine new stations included in the contemporaneous model and the Comparison Group I boundaries (see Figure 17 in the Appendix).

The anticipatory combined model using the Comparison Group II definition of bridge proximity is presented in Table 16. The results of the solitary anticipatory model using the Comparison Group II definition of bridge proximity referenced in the following discussion are from Table 13. The impact of controlling for the spatial presence of the light rail does not produce any significant variations in the estimated coefficient of *Toll-Weight X Proximity 520* between the anticipatory model in Table 13 and the combined model results displayed in Table 16. The estimates for both *Δ Anticipatory X Retro X Qtr-Mile* and *Δ Anticipatory X New X Qtr-Mile* fluctuate between the solitary and combined regressions, although the difference in estimates across regression specification is much smaller using the Comparison Group II definition of bridge proximity than the Comparison Group I

[15] Recall a station is included in the anticipatory model if it is under construction during the panel.

definition of bridge proximity.

Unlike in the Comparison Group I combined model, *Δ Anticipatory X New X Qtr-Mile* exhibits less variation between the solitary and combined estimates than *Δ Anticipatory X Retro X Qtr-Mile*. However, the variation across the station variables between the solitary and combined models is mitigated when using the Comparison Group II definition of bridge proximity. Once the Comparison Group II presence of the toll is accounted for, tracts with 100 percent of residential area within a ¼ mile of retrofit stations are associated with a gain of 1,987 residents per square mile (from 1,524 in the solitary model) and 1,084 additional housing units per square mile (from 1,076 in the solitary model). The average tract with any residential area within a ¼ mile of a retrofit station could expect to observe a gain of 974 residents and 531 housing units from 2004 through 2010. Tracts with 100 percent of residential area within a ¼ mile of new stations are associated with a gain of 2,450 residents per square mile (from 2,571 in the solitary model) and 658 new housing units per square mile (from 730 in the solitary model). The average tract with any residential area within a ¼ mile of a new station could expect to observe an increase in population of 221 residents per square mile and an increase in housing units of 59 units per square mile from 2004 through 2010. The magnitudes of *Δ Anticipatory X Retro X Qtr-Mile* and *Δ Anticipatory X Retro X Qtr-Mile* within the Δ *Lag Black* and Δ *Age* vary widely between the solitary and combined models. However, as within the estimate of the toll's impact using the Comparison Group I definition of bridge proximity, the coefficients produced are of minor importance due to their insignificant size.

The reduction in the variation between the station variables of interest between the solitary and combined models when using the Comparison Group II definition of bridge proximity may be a function of the spatial relationship between both station types and the Comparison Group II boundaries. Within the anticipatory model, ten of the fifteen new stations and all four retrofit stations fall within the Comparison Group II boundaries (see Figure 18 in the Appendix), implying the change in transitioning from the solitary to the combined model is applied to both station types, potentially reducing the variation across each station's coefficient between the two regression specifications. As before, the two station variables exhibit greater fluctuations between the solitary and combined models than the toll variable. Since fourteen of the nineteen total stations are either fully or partially encompassed within the Comparison Group II boundaries and only a small portion of the Comparison Group II area overlaps with the station vicinities, the station variables are subjected to a tighter control environment in the transition from the solitary to combined model than the toll variable.

The contemporaneous combined model using the Comparison Group II definition of bridge proximity is displayed in Table 44 in the Appendix. There are no changes in the impact of the toll on the population and demographic variables once the light rail's spatial presence is controlled for (see Table 14 for the contemporaneous Comparison Group II toll model), while there are only minor changes in *Δ Station Operational X Retro X Qtr-Mile* and *Δ Station Operational X New X Qtr-Mile* once the toll's impact within the Comparison Group II boundaries is controlled for (see Table 10 for the contemporaneous light rail model). As in the Comparison Group I models, the variation between the station terms of interest across the solitary and combined models using the contemporaneous approach is far less than in using the anticipatory approach. As before, the smaller variation across the station variables of interest between the solitary and combined models within the contemporaneous specification is likely due to the stations included within each model specification. Fifteen of the nineteen total stations within the anticipatory model possess some degree of overlap with the Comparison Group II boundary (see Figure 18 in the Appendix), whereas nine of the thirteen stations within the contemporaneous model overlap with the Comparison Group II boundary (Figure 19 in the Appendix). Thus, in transitioning from the solitary to combined models, the stations included within the contemporaneous specification are subjected to less change in the control environment relative to the stations included within the anticipatory specification once the Comparison Group II boundaries are controlled for.

The smaller degree of variation between the solitary and combined models within the contemporaneous model relative to the anticipatory model across both bridge proximity definitions may also be a function of the temporal designation of each intervention's opportunity for impact. Within the anticipatory model, the light rail is activated from 2004 through 2010, whereas the toll is activated from 2009 through 2014. Within the contemporaneous model, there is no temporal overlap between the two interventions: the light rail is activated in 2010 and the toll is activated from 2012 through 2014. Thus, the contemporaneous model interprets the interventions as entirely distinct temporally, without the ability to interact.

The general consistency of results between the estimated coefficients regarding the toll's impact between the solitary and combined models stands in stark contrast to the often large differences in the estimated coefficients on the station variables of interest, especially within the anticipatory model. Since the light rail impact areas encompass less surface area than the toll impact areas, the inclusion of an additional influence with overlapping spatial criterion into the model accounts for a greater percentage of the total surface area occupied by the light rail. Light rail impact areas are also generally disjointed (other than the retro-station impact areas), potentially adding difficulty in distinguishing impacts from the light rail from impacts attributable to other heterogeneous sources. On the other hand, the toll's impact area within each Comparison Group is a continuous, uninterrupted swath.

VIII. Employment Results

VII.A. Overview

The operation of both the light rail and toll are affecting employment density distributions across the Seattle metropolitan region, whereas only the light rail has impacted the location of public sector employment. Employment density has decreased within a ¼ mile of retrofit and new light rail stations, likely as a result of displacement in favor of establishing residential habitations (see Table 9 in *Section VII - Population and Demographic Results*). However, employment density increased by an economically significant margin within two miles of the SR-520 termini and also increased within 1.5 miles of a ramp within five miles of the SR-520 termini, although the magnitude is smaller. The prevalence of public sector employment declined disproportionately around new light rail stations, with the decline being amplified given the small initial base of public sector jobs around new stations. The light rail has no significant impact on public sector employment around retrofit light rail stations, and the toll is not associated with any change in the prevalence of public sector employment. Results are presented in accordance with the model specification deployed and the geographical measurement of proximity used for the toll. Five fewer tracts are included in the following regressions due to a lack of a complete panel of employment-related data.

VIII.B. Light Rail Estimation

As in *Section VII*, the impact of the light rail on employment density is sensitive to both model specification and station type, highlighting the importance of controlling for observed reaction time and the preexisting urban form surrounding stations. The magnitude of the decline in employment density surrounding retrofit stations ranges from a loss of 15,754 jobs per square mile to 24,592 jobs per square mile for a tract with 100 percent of its nonresidential area within a ¼ mile of a retrofit station. The decline in employment density surrounding new stations is smaller in magnitude and ranges from a loss of 744 jobs per square mile to 1,439 jobs per square mile for a tract with 100 percent of its nonresidential area within a ¼ mile of a new station. However, a log transformation of total employment indicates that new station areas lost a greater percentage of total employment than retrofit station areas, underscoring the importance of making relative comparisons between spatial designations. Regressions inclusive only of tracts with any portion of area within a ½ mile of stations are available in the Appendix for both the anticipatory and contemporaneous specifications (Table 45 and Table 46, respectively).

The light rail does not have a definitive impact on the prevalence of public sector employment within a ¼ mile of retrofit stations but is associated with a large percentage decline in public sector employment within a ¼ mile of new stations. The impact from the light rail on the prevalence of public sector employment within a ¼ mile of retrofit stations increases from 1 percent to 4 percent between the anticipatory and contemporaneous models, suggesting any displacement of public sector employment that may have occurred during the construction process was temporary. The prevalence of public sector employment increases between 5 percent and 6 percent within a ½ mile of retrofit stations within the anticipatory and contemporaneous models (Table 47 and Table 50). The impact of the light rail on the prevalence of public sector employment within a ¼ mile of new stations is consistently large and negative across both the anticipatory and contemporary model specifications, ranging from a decline of 36 to 38 percent of public sector jobs. However, this negative effect is mitigated upon an expansion of the radius around stations: within ½ mile of new stations, the light rail system is associated with a 12 percent decline

Table 17 - Effect of Light Rail on Employment Characteristics, Anticipatory Model		
	Dependent Variable	
	Δ Employment Density	Δ Pct. Public Jobs
Independent Variable		
Δ Lag Employment Density	-0.0379**	4.21e-08
	(0.0177)	(3.16e-07)
Δ Lag Black	3,500	-0.185
	(11,677)	(0.210)
Δ Age	32.75	-0.00139
	(155.3)	(0.00278)
Δ Education	-583.1	-0.0240
	(1,317)	(0.0236)
Δ Lag Income	0.000806	1.33e-07
	(0.00786)	(1.40e-07)
Δ Lag Unemployment	-5,637**	0.0405
	(2,659)	(0.0476)
Δ Lag Poverty	-1,823	0.0293
	(1,690)	(0.0302)
Δ Commute Length	-410.8	0.0118
	(1,156)	(0.0207)
Δ Pct. Utilizing Public Transit	-2,412	0.0167
	(1,736)	(0.0310)
Δ Home Price	-0.000181*	2.44e-09
	(0.000101)	(1.80e-09)
Initial value	0.0173***	-0.0208***
	(0.00273)	(0.00521)
Distance to CBD	3.280	6.36e-05
	(12.60)	(0.000225)
Distance to freeway	5.907	-0.000501
	(31.82)	(0.000567)
Percent Commuting to CBD	406.3	0.0137
	(855.7)	(0.0147)
Pct. Nonresidential	51.98	0.00115
	(111.0)	(0.00190)
Δ Anticipatory X Retro X Qtr-Mile	-24,592***	0.0124
	(6,541)	(0.101)
Δ Anticipatory X New X Qtr-Mile	-744.4	-0.376***
	(4,585)	(0.0826)
Observations	3,159	3,159
Number of tract	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

and a 14 percent decline across the anticipatory and contemporaneous specifications, respectively (Table 47 and Table 50).

The results of the anticipatory model specification are displayed in Table 17. Figure 26 displays total employment within a ¼ mile of all anticipatory stations over the course of the panel. The light rail appears to have a negative impact on the density of employment within a ¼ mile of each station type over the course of the system's construction and during its first year of operation. *Δ Anticipatory X Retro X Qtr-Mile* in Table 17 indicates that, for a tract with 100 percent of its nonresidential area within a ¼ mile of a retrofit light rail station, the system is associated with a decline of 24,592 jobs per square mile from 2004 through 2010. This impact is reduced slightly to a decline of 24,054 jobs per square mile once the operation of the toll is accounted for (see Table 48 in the Appendix).

Examining the applicable study area tracts' spatial relationship with the location of retrofit stations provides some additional context to the results: ten tracts have a positive percentage of their nonresidential area within a ¼ mile of a retrofit station. The mean percentage of these ten tracts' nonresidential area within a ¼ mile of the four retrofit stations is 31 percent, indicating that the potential observed decrease in employment density for tracts with any nonresidential area within a ¼ mile of a retrofit station from 2004 through 2010 is approximately 7,623 jobs. The average tract with any nonresidential area within a ¼ mile of a retrofit station had an employment density of 32,841 in 2004, indicating the model's predicted decrease of 7,623 amounts to a 23 percent decline in employment density from 2004 through 2010.

The decline in employment density associated with the light rail was much smaller in absolute terms surrounding new stations, as is apparent by the magnitude of *Δ Anticipatory X New X Qtr-Mile* in Table 17. For a tract with 100 percent of its nonresidential area within a ¼ mile of a new station, the light rail is associated with a decrease of 744 jobs per square mile from 2004 through 2010. Once the operation of the toll is controlled for, the decline in employment density is almost identical to the results displayed in Table 17, with employment density declining by 719 jobs per square mile for a tract with 100 percent of nonresidential area within a ¼ mile of a new station (see Table 48 in the Appendix). There are a total of 31 tracts[16] with a portion of nonresidential area within a ¼ mile of the fifteen new light rail stations included in the anticipatory model. The mean percentage of total nonresidential area within a ¼ mile of a new light rail station is 23 percent, implying that the model predicts the observed decrease in total jobs surrounding new stations from 2004 through 2010 for the nine original new stations and from 2012 through 2014 for the four new stations under construction during the panel is approximately 171 jobs. The 31 tracts with any nonresidential area within a ¼ mile of one of the fifteen new stations had an average employment density of 4,886 in 2004, indicating the light rail may be associated with a decline of less than 1 percent in employment density around new stations. Likely due to the onset of the Great Recession in 2008, non-station tracts within the study area experienced negligible increases in employment. The average non-station tract had an employment density of 1,160 at the beginning of 2004 and gained 12 jobs by 2010, indicating a 1 percent increase in employment density.

Although Table 17 and the above discussion indicates a massive outflow of employment from retrofit station areas and only a minor decline in employment around new stations, a log transformation of total employment (not *employment density* as is displayed in Table 17) provides an alternative perspective (see Table 49 in the Appendix). Δ *Anticipatory X Retro X Qtr-Mile* in Table 49 indicates that a tract with 100 percent of its nonresidential

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[16] Recall that one tract has a portion of its residential area within a ¼ mile of both a retrofit station and a new station.

area within a ¼ mile of a retrofit station would lose 14 percent of total employment, whereas Δ *Anticipatory X New X Qtr-Mile* indicates a tract with 100 percent of its nonresidential area within a ¼ mile of a new station would lose 52 percent of total employment. As in the discussion pertaining to observed density changes in *Section VII*, the lack of the alignment between the percentage changes produced within the log results and the prediction of potential observed percentage decreases may be a result of the different measurements used (total employment is used within the log regressions and employment density is used within Table 17), the average employment density values from 2004 are not weighted to take a tract's percentage of nonresidential area within a ¼ mile of a station into account and the tracts included within the average density values post large variances that is not captured in the mean reported value.

The literature has generally found increases in employment density around light rail stations. In Dyett et al.'s (1979) examination of the economic impact of BART, a survey was disseminated to the region's fifty largest employers. Five employers noted that they were directly motivated to relocate towards a BART station in order to gain access to employees and customers. Dyett et al. also find that "communities served by BART increased their share of new office construction markedly – from 6 percent during the years 1963 to 1965 (the years immediately before the construction of BART began) to 14 percent in the years 1974 to 1976 (immediately after the completion of BART's last major section." This increase in demand from employers to locate in communities served by BART may reflect that "four cities enacted zoning changes that encouraged commercial construction near stations," and may also be the function of a less precise boundary of impact used within the Dyett et al. work (communities versus a ¼ mile radius). Cervero et al.'s (1995) more recent BART impact study finds larger employment effects. Notable impacts include the addition of 55,000 square feet of commercial space within a ½ mile of the Fremont station, 28 million square feet of office space constructed within a ½ mile of the four downtown stations,1.5 million square feet of office space within a ¼ mile of the Pleasant Hill station and a gain of 4 million square feet of office space within a ½ mile of a station on the Concord Line. Bollinger and Ihlandfelt (1997) quantify changes in employment around Atlanta's stations by node-type over the first eleven years of the system's operation. They determine public-sector employment expanded within a ¼ mile of Atlanta's mixed-use stations, increasing by 2,979 public-sector jobs. However, most other sectors realized decreases in total employment within a ¼ mile of stations, with commuter stations losing 825 manufacturing jobs and the transportation, communication and utility sector losing 657 jobs within a ¼ mile of mixed use stations.

As retrofit stations are located in the heart of the CBD, they are surrounded by many multi-story buildings. The large decline in employment density surrounding retrofit stations displayed in Table 17 may be the result of a conversion of space from commercial to residential usage, assisting in the rapid increase of 1,076 housing units surrounding retrofit stations observed in Table 9. With a mass exodus of firms and businesses, property owners may have been able to quickly convert prior business establishments to residential units, whereas entirely new structures may have had to be constructed surrounding new stations.

As is apparent from the comparison of log regression results between the two station types in Table 49 relative to the absolute job losses displayed in Table 17, the job losses in the CBD captured around retrofit stations do not amount to the same relative decline in total employment as is observed in the much less dense new station areas. The preexisting urban form surrounding new stations may have contributed to its larger relative decrease in employment figures: the relaxation of spatial constraints as distance increases to the CBD allowed for the light rail track to be laid on the streets (as opposed to the subterranean track laid in parts of the CBD) and parking garages to be erected nearby. Thus, the light rail and its associated facilities occupy additional surface area as distance to the CBD increases, further displacing existing firms.

The impact of the light rail on public sector employment within a ¼ mile of stations is also dependent on station type within the anticipatory model, as is displayed in Table 17. The model predicts that, over the course of the system's construction and first year of operation, a tract with 100 percent of its nonresidential area within a ¼ mile of a retrofit station would observe a 1 percent increase in public sector employment, whereas a tract with 100 percent of its nonresidential area within a ¼ mile of a new station would observe a 38 percent decline in public sector employment. The model's prediction of a 38 percent decline in public sector employment in tracts with 100 percent of their nonresidential area within a ¼ mile of a new station area tracts converts to an absolute decline of 592 government jobs within a ¼ mile of the fifteen new stations in the anticipatory model from 2004 through 2014. When considered relative to new station areas' decrease in total employment, public sector employment declined disproportionately. In 2004, 15.5 percent of total employment within a ¼ mile of new stations derived from the public sector. By 2010, this figure had declined to 13.4 percent. Regardless of the decline in the prevalence of government employment around new stations, the employment composition within a ¼ mile of both station types is skewed in favor of the public sector relative to the rest of the study area, potentially reflecting a perspective of the importance of maintaining the accessibility of government services: within the entire study area, public sector jobs represented 7.6 percent and 7.7 percent of all jobs in 2004 and 2010, respectively.

The greater relative decrease in public sector employment around new stations compared to retrofit stations may reflect the City's urban development goal of concentrating residential development around public transit modes. Since the City has the authority to relocate governmental establishments and new stations may provide more of an opportunity for the City to develop transit oriented communities, the City may prioritize relocating governmental services that were initially located around new stations. There may also be an incentive for the City to maintain governmental establishments in inner city locations and close-in proximity to bus stations, explaining the rebound of total government employment within a ¼ mile of retrofit stations once the light rail system became operational (Table 18). If one assumes lower income individuals and minorities are more likely to access government services and live in the dense inner city, then locating government services around transit hubs in the CBD increases their accessibility to these constituents. Since retrofit stations offer bus services as well as light rail services, an individual without a personal vehicle would be able to easily access most areas of the region through the different transit modes provided at these stations.

Several other variables in Table 17 provide additional insight as to the factors influencing firms' locational decisions. Δ *Lag Unemployment* indicates prior high levels of unemployment are a significant drag on economic growth and are associated with a lack of current firms expanding and new firms from locating in the area: a tract with a 100 percent unemployment rate would experience a decline in employment density of 5,637 relative to a tract with an unemployment rate of zero. Increases in Δ *Pct. Utilizing Public Transit* are associated with a decrease in employment density in the corresponding tract, with a tract with 100 percent public transit users having an employment density that is 2,412 jobs per square mile lower than a tract with no public transit users. This decrease in employment density in areas experiencing a surge in public transit patronage coincides with the movement of firms away from station areas, as is observed by the negative coefficients previously discussed associated with *Retro X Anticipatory X Qtr-Mile* and *New X Anticipatory X Qtr-Mile.* A one-mile increase in *Distance to CBD* is associated with only three more jobs per square mile, much smaller than one may expect if assuming the main hub of commercial activity in a metropolitan area is the CBD. However, the highly metropolitan and population dense area of Bellevue, Washington is approximately ten miles from the CBD and may provide a neutralizing influence on what would otherwise likely be an economically significant impact of increasing distance to the CBD. *Pct. Nonresidential* is also negligible in both economic and statistical terms. This may be attributed to highly nonresidential tracts being dominated by industrial and manufacturing firms where the number of workers per square foot of a firm's domain is low.

The results from the contemporaneous specification in Table 18 suggest that a large portion of the decline in total employment figures around both station types occurred during the system's first year of operation. Figure 27 in the Appendix displays the annual trend of total employment within a ¼ mile of stations included in the contemporaneous model. In Table 18, *Δ Station Operational X Retro X Qtr-Mile* and *Δ Station Operational X New X Qtr-Mile* indicate that, during 2010, a tract with 100 percent of its nonresidential area within a ¼ mile of a retrofit station would experience a decline in employment density of 15,754 jobs per square mile and a tract with 100 percent of its nonresidential area within a ¼ mile

Table 18 - Effect of Light Rail on Employment Characteristics, Contemporaneous Model

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public Jobs
Independent Variable		
Δ Lag Employment Density	-0.0705***	1.35e-07
	(0.0176)	(3.11e-07)
Δ Lag Black	3,558	-0.180
	(11,453)	(0.205)
Δ Age	70.74	-0.000232
	(152.3)	(0.00271)
Δ Education	-499.6	-0.0156
	(1,293)	(0.0230)
Δ Lag Income	0.000462	1.27e-07
	(0.00770)	(1.37e-07)
Δ Lag Unemployment	-5,851**	0.0353
	(2,607)	(0.0464)
Δ Lag Poverty	-1,763	0.0228
	(1,657)	(0.0295)
Δ Commute Length	-182.2	0.00921
	(1,132)	(0.0201)
Δ Pct. Utilizing Public Transit	-1,316	0.00178
	(1,703)	(0.0303)
Δ Home Price	-0.000184*	2.28e-09
	(9.87e-05)	(1.76e-09)
Initial value	0.0184***	-0.0176***
	(0.00236)	(0.00505)
Distance to CBD	3.210	3.37e-05
	(12.32)	(0.000218)
Distance to Freeway	6.130	-0.000484
	(31.20)	(0.000553)
Percent Commuting to CBD	429.4	0.00983
	(834.5)	(0.0139)
Pct. Nonresidential	52.25	0.000192
	(107.6)	(0.00183)
Δ Station Operational X Retro X Qtr-Mile	-15,754***	0.0401*
	(1,350)	(0.0234)
Δ Station Operational X New X Qtr-Mile	-1,439	-0.356***
	(1,501)	(0.0268)
Observations	3,159	3,159
Number of tract	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

of a new station would experience a decline in employment density of 1,439 jobs per square mile, respectively. These magnitudes convert to a decline in employment density of 4,888 and 331 jobs per square mile for tracts with any nonresidential area within a ¼ mile of a retrofit station and new station during 2010, respectively.

When considered in context with the results from the anticipatory specification, these figures indicate that over half of the expected job losses in tracts adjacent to retrofit stations over the seven-year anticipatory period occur in the year of the system's opening (relative to the 24,592 decrease in employment density displayed in Table 17). The larger loss of employment of 1,439 signified by *Δ Station Operational X New X Qtr-Mile* in Table 18 relative to the loss of employment of 744 signified by *Δ Anticipatory X New X Qtr-Mile* in Table 17 indicates the anticipatory period includes years with job *gains* within a ¼ mile of new stations or that employment figures declined more around the subset of nine new stations included within the contemporaneous model relative to the fifteen new stations included within the anticipatory model (see Figure 26 and Figure 27). Since the contemporaneous specification only accounts for tracts that were operational in 2010, fewer new stations are included than in the anticipatory specification.

There are a total of sixteen tracts with any portion of their nonresidential area within a ¼ mile of the nine new stations that opened in 2010. Of these sixteen tracts, the average percentage of nonresidential area within a ¼ mile of a new station is 22 percent, while the minimum and maximum percentages are 2 percent and 73 percent, respectively. As in the anticipatory specification, the numbers presented in Table 18 indicate the total predicted change in employment density for a tract with 100 percent of nonresidential area within a ¼ mile of the given station type, implying any observed decreases in total employment would be less than the values displayed in the table.

The difference in magnitude of the variables of interest across the anticipatory and contemporaneous specifications provide additional context to the interpretation of the timing of firms' responses to the light rail system. The decrease of 15,754 jobs per square mile within a ¼ mile of retrofit stations during the system's first year of operation indicates the estimated 24,592 decline in jobs per square mile from the anticipatory specification was a culmination of a gradual decline over the construction phase in addition to the large, abrupt decline in 2010. Given the still steady increase in housing units occurring around retrofit stations in 2010 of 124 units (see Table 10), the City may have allowed larger firms to stay in the vicinity of retrofit stations until their space was required to convert into residential units. This gradual decline in employment around retrofit stations from 2004 through 2009 in conjunction with the large decline in 2010 is supported by this theory of displacement of firms due to construction followed by a large, abrupt conversion from commercial space to residential units once the system was ready to commence. Also, while it may be possible to fill vacant residential units and add extensions to apartment buildings to increase population and housing density, the often greater amount of square feet required by employers may further limit the ability of firms to remain or locate in areas that are experiencing a surge in population.

The difference in magnitude of the decrease in employment density within a ¼ mile of new stations across the anticipatory and contemporaneous regressions may be evidence of either firm response to the light rail system, City policy or simply a reflection of a variation in employment changes across the different stations included within each regression specification. The estimated employment displacement of 1,439 jobs per square mile in the contemporaneous model could not be due to the system's initial construction since, by

2010, the system was operational. Thus, the large and abrupt decline in employment density within a ¼ mile of new stations during the system's first full year of operation could be the result of firms perceiving the light rail as a potential attraction for loiterers or firms being forced to relocate due to the initiation of new construction on large scale residential developments. Additionally, residential dwellings may have been renovated and expanded around new stations prior to displacing firms in order to ensure that there would immediately be residents near the station, ready to utilize the system. Thus, there may have been small fluctuations in employment density (as could be suggested in Table 17) until the year of opening when the City transitioned facilities that did not cater to the neighborhood lifestyle to residential dwellings, resulting in a massive decline in employment numbers in the year of opening. Finally, employment density within a ¼ mile of the fifteen new stations included in the anticipatory regression may simply have declined less than employment density within a ¼ mile of the nine new stations included in the contemporaneous regressions.

The contemporaneous specification suggests that government sector employment was in the process of rebounding within a ¼ mile of retrofit stations and was still declining rapidly within a ¼ mile of new stations during the system's first year of operation. The contemporaneous specification predicts a tract with 100 percent of its nonresidential area within a ¼ mile of a retrofit station would experience a 4 percent increase in the prevalence of public sector employment in 2010, relative to a 1 percent increase over the course of the anticipatory period displayed in Table 17. This increase in the prevalence of public sector employment may reflect the City's attempt to maintain a certain degree of accessibility to public services for public transit users. Since retrofit stations offer both light rail and bus services, a greater swath of the public may be represented by the individuals who utilize these stations. Thus, it may be advantageous to locate governmental offices near retrofit stations to ensure accessibility to individuals who utilize multiple transit mediums. Another factor potentially affecting the increased prevalence of public sector jobs within a ¼ mile of retrofit stations during the system's first year of operation may be the decline in the base number of jobs of 15,754 in 2010, allowing for public sector jobs to gain a larger share of total employment without experiencing a large absolute increase. However, regardless of the relative percentage of total jobs, the absolute number of government jobs within a ¼ mile of retrofit stations increased from 10,442 in 2009 to 10,652 in 2010.

The estimated impact from the light rail on the prevalence of public sector employment within a ¼ mile of new stations is nearly equivalent between the anticipatory and contemporaneous specification, with the anticipatory specification estimating a 38 percent decline in the prevalence of public sector employment and the contemporaneous specification estimating a decline of 36 percent. Although there were several years with *total* job gains within a ¼ mile of new stations over the anticipatory period, the total number of *government* jobs in this vicinity declined each year of the panel, displaying a concerted effort on behalf of the City to relocate facilities within its jurisdiction. However, the largest decline in the total number of government jobs within a ¼ mile of new stations occurred during the system's first year of operations. The total number of public sector jobs decreased from 2,728 to 2,321 around the nine new stations in the contemporaneous model during 2009, paralleling the large decline in total employment within a ¼ mile of new stations in the
same year.

Regressions using a proximity measurement of a ½ mile around both station types are available in Table 47 and Table 50 in the Appendix. The models predict that a tract with 100 percent of nonresidential area within a ½ mile of a retrofit station would lose between 6,535 and 12,804 jobs per square mile. The average tract with a positive percentage of nonresidential area within a ½ mile of retrofit station has 50 percent of nonresidential area within a ½ mile of a retrofit station, bringing the expected changes in employment density within a ½ mile of a retrofit station to 3,268 and 6,402 across the contemporaneous and anticipatory specifications. The light rail system is associated with a loss of 745 jobs per square mile to a *gain* of 4,597 jobs per square mile for a tract with 100 percent of nonresidential area within a ½ mile of a new station. Within the contemporaneous model, the average tract with any nonresidential area within a ½ mile of a new station has 41 percent of nonresidential area within a ½ mile of a new station. Applying this mean to the model's predicted decline of 745 jobs results in an expected decrease of 305 jobs within the average tract with any nonresidential area within a ½ mile of a new station. Within the anticipatory model, the average tract with any nonresidential area within a ½ mile of a new station has 33 percent of nonresidential area within a ½ mile of a new station, implying the expected change in employment density is a gain of 1,517 jobs per square mile. These vast disparities between the results from the ¼ mile proximity measurement and the ½ mile proximity measurement convey an intense policy of displacement of commercial activity within a ¼ mile of stations, with relocations occurring between a ¼ mile and ½ mile of stations. This policy appears to be exercised with more precision surrounding the new stations that are not yet operational that are included within the anticipatory model, as these stations experience significant increases in employment density over the panel. Figure 24 and Figure 25 in the Appendix display total employment within a ½ mile of all stations in the anticipatory and contemporaneous models, respectively.

VIII.C. Toll Estimation

In vicinities near the SR-520, the operation of the toll is associated with an increase in employment density and is not associated with a change in the prevalence of public sector employment. The toll is associated with an increase in employment density of 385 to 453 jobs per square mile within two miles of the SR-520 termini and with an increase in employment density of 84 to 126 jobs per square mile within 1.5 miles of a ramp within five miles of the SR-520 termini. Controlling for the operation of the light rail does not change the economic or statistical significance of the results. There is no measurable effect from the toll when the impact is quantified using distance to the SR-520 termini.

VIII.C.I. Comparison Group I

Table 19 displays the results of the anticipatory model specification using the Comparison Group I definition of proximity. Recall that Comparison Group I measures the impact from the toll using the percentage of a tract's nonresidential area within two miles of the SR-520 termini. *Toll Anticipatory Wgt. X Proximity 520* in Table 19 indicates a tract with 100 percent of nonresidential area within two miles of the SR-520 bridge termini would experience an increase in employment density of 453 jobs per square mile between 2009 and 2014. As in the prior estimations, the values in the tables below are overestimates of any observable impact: of the 28 tracts with a positive percentage of nonresidential area within two miles of the SR-520 termini, the average percentage of nonresidential area is 60 percent while the minimum and maximum are 1 percent and 100 percent, respectively. This indicates the average tract with any nonresidential area within two miles of the SR-

520 termini may have experienced an increase in employment of 272 jobs from 2009 through 2014.

The increase in employment density of 453 jobs per square mile in tracts nearest the SR-520 bridge may suggest firms perceive the toll as allowing for greater access to employees, customers or both. With the increased frequency and availability of public transit coinciding with the implementation of the toll (see *Section II)*, employers may interpret the toll as facilitating additional transit options for commuters. Further, the toll has coincided with a slight increase in population density within two miles of the SR-520 bridge termini (Table 11). Since individuals residing within two miles of the lake may be more likely to have attained advanced degrees due to the extremely high value of property in this area, employers may believe their ideal employment base is easily accessible and the available customers not only have a great deal of discretionary income but are also increasing in number. Additionally, the stagnant growth in housing unit density within two miles of the SR-520 termini (Table 11) may signal a lessening of the capacity constraints within the two-mile SR-520 termini boundaries, perhaps leading to a decline in rents.

Additional regression specifications allow for an understanding of the sensitivity of the results in Table 19. Table 52 in the Appendix displays results from the anticipatory regression specification when controlling for the operation of the light rail in 2010 through the end of the panel. Once the light rail is controlled for, the model predicts a tract with 100 percent of its nonresidential area within two miles of the SR-520 termini would experience an increase in employment density of 455 jobs per square mile upon the announcement of the toll through the end of the panel. Although Table 19 and Table 52

Table 19 – Effect of Toll on Employment Characteristics, Anticipatory Model and Comparison Group I Proximity Measurement

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0386**	1.65e-08
	(0.0177)	(3.16e-07)
Distance to CBD	1.803	8.15e-05
	(13.51)	(0.000239)
Percent Commuting to CBD	346.9	0.0169
	(973.6)	(0.0159)
Eastside	82.69	0.00173
	(96.31)	(0.00168)
Δ Lag Black	-847.8	-0.167
	(11,904)	(0.215)
Δ Lag Income	0.00244	1.43e-07
	(0.00786)	(1.41e-07)
Δ Lag Unemployment	-5,886**	0.0427
	(2,664)	(0.0477)
Δ Lag Poverty	-1,591	0.0302
	(1,696)	(0.0304)
Δ Age	-14.93	-0.00153
	(157.4)	(0.00282)
Δ Education	-901.8	-0.0238
	(1,330)	(0.0238)
Δ Commute Length	-374.1	0.0220
	(1,163)	(0.0208)
Δ Pct. Utilizing Public Transit	-2,798	0.00574
	(1,735)	(0.0311)
Initial Value	0.0131***	-0.0261***
	(0.00247)	(0.00537)
Pct. Nonresidential	66.31	0.000694
	(109.9)	(0.00186)
Toll Anticipatory Weight	37.01	-0.00240*
	(74.23)	(0.00133)
Proximity 520	-327.0	-0.00346
	(250.5)	(0.00449)
Proximity I-90	-152.2	-0.00274
	(153.2)	(0.00274)
Toll Anticipatory Wgt. X Proximity 520	452.6	0.00325
	(370.5)	(0.00664)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

produce nearly identical results, the toll fails to produce any significant impact on employment density once proximity to the bridge is measured as the distance to the SR-520 termini: *Anticipatory Weight X Distance to 520* in Table 53 in the Appendix indicates that, upon the announcement of the toll in 2009, a one mile increase in distance to the SR-520 termini is associated with 4 fewer jobs per square mile.

The results presented in Table 19 are able to be considered in a wider context upon a log transformation of total employment. *Toll Anticipatory Wgt. X Proximity 520* in Table 54 in the Appendix suggests a tract with 100 percent of its nonresidential area within two miles of the SR-520 termini would observe an increase in total employment of 7.4 percent upon the announcement of the toll through the end of the panel. This increase in total employment within two miles of the SR-520 termini upon the announcement of the toll (2009 through 2014) stands in stark contrast to the lower total employment figures within two miles of the SR-520 termini boundaries from 2004 through 2014: total employment within the two-mile boundary surrounding the SR-520 termini is 6 percent lower than the rest of the study area (*Proximity 520* in Table 54) over the entire panel. Total employment within two miles of the I-90 termini is 1 percent lower than the rest of the study area (*Proximity I-90* in Table 54). Although it is likely that the relatively lower employment density surrounding the bridges are partially a function of higher rents, the sudden growth in employment density coinciding with the implementation of the toll suggests the toll *is* the catalyst for the increase in employment density near the SR-520 bridge.

The negative association between employment density and bridge proximity across the entire panel (as is suggested by *Proximity 520* in Table 54) does not hold upon an

Table 20 – Effect of Toll on Employment Characteristics, Contemporaneous Model and Comparison Group I Proximity Measurement

	Dependent Variable	
	Δ Employment Density	Δ Pct Public
Independent Variable		
Δ Lag Employment Density	-0.0392**	2.38e-08
	(0.0177)	(3.17e-07)
Distance to CBD	1.422	9.24e-05
	(13.51)	(0.000239)
Percent Commuting to CBD	343.4	0.0172
	(973.4)	(0.0159)
eastside	83.23	0.00171
	(96.29)	(0.00168)
Δ Lag Black	-440.9	-0.168
	(11,912)	(0.215)
Δ Lag Income	0.00294	1.36e-07
	(0.00785)	(1.41e-07)
Δ Lag Unemployment	-5,980**	0.0417
	(2,663)	(0.0477)
Δ Lag Poverty	-1,552	0.0290
	(1,696)	(0.0304)
Δ Age	10.18	-0.00225
	(156.2)	(0.00280)
Δ Education	-909.3	-0.0242
	(1,328)	(0.0238)
Δ Commute Length	-467.8	0.0218
	(1,165)	(0.0209)
Δ Pct. Utilizing Public Transit	-2,822	0.00577
	(1,736)	(0.0311)
Initial Value	0.0131***	-0.0261***
	(0.00247)	(0.00537)
Pct. Nonresidential	69.13	0.000597
	(109.8)	(0.00186)
Toll Operational	71.22	-0.00183
	(66.98)	(0.00120)
Proximity520	-229.5	-0.00280
	(201.1)	(0.00361)
Proximity I-90	-152.7	-0.00271
	(153.2)	(0.00274)
Toll Operational X Proximity 520	385.4	0.00291
	(333.9)	(0.00598)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

examination of the relationship between employment density and distance to either bridge: both *Distance to I-90* and *Distance to 520* are statistically and economically insignificant in Table 53 in the Appendix. This lack of a relationship between distance to the tolled bridge and employment density suggests that employment density may be sensitive to locating very near either bridge but, outside of these narrow boundaries, it is not a function of total mileage removed from the bridges. The operation of the toll has not impacted the distribution of public sector employment relative to the SR-520 bridge. *Toll Anticipatory Wgt. X Proximity 520* in Table 20 indicates public sector employment increased by 0.3 percent within two miles of the SR-520 termini once the toll was announced in 2009 through the end of the panel. Additional specifications imply that the negligible response of public sector employment to the toll is robust to various model adjustments: the increase in public sector employment of 0.3 percent in a tract with 100 percent of its nonresidential area within two miles of the SR-520 bridge termini is supported once the operation of the light rail is accounted for (Table 52 in the Appendix). *Anticipatory Weight X Distance to 520* in Table 53 in the Appendix further confirms that the prevalence of public sector employment did not change upon the implementation of the toll as one varies the distance from the bridge.

The results from the contemporaneous model are presented in Table 20. *Toll Operational X Proximity 520* indicates that a tract with 100 percent of its nonresidential area within two miles of the SR-520 termini would experience an increase in employment density of approximately 385 jobs per square mile once the toll became operational in 2012 until the end of the panel in 2014. Since the average percentage of nonresidential area within two miles of the SR-520 termini amongst all tracts with any nonresidential area within two miles of the SR-520 termini is 60 percent, this implies that the expected observed increase in employment is 231 jobs per square mile from 2012 through 2014. A comparison between the coefficient produced in both the anticipatory and contemporaneous models suggests maintaining *Toll Operational* as a level (as opposed to a difference as in the light rail specification) is appropriate: 385 of the 453 additional jobs per square mile that may be generated in a tract with 100 percent of its nonresidential area within two miles of the SR-520 termini from 2004 through 2014 are only added once the toll is operational. Thus, employers may have anticipated the toll would drive residents away from the SR-520 termini vicinities and create a barrier to a qualified labor force but, upon realization of the extended public transit services and the slight influx of residents to the area, began to perceive as the toll as a benefit as opposed to a cost. Any quantification of the toll's impact solely as a difference would not capture this shifting in employment figures that occurs post implementation, supporting the prior supposition that households and firms may not react to an intervention perceived as a cost until the cost is realized. The lack of impact from the toll on the prevalence of public sector employment is supported again in the contemporaneous model, with *Toll Operational X Proximity 520* indicating that a tract with 100 percent of its nonresidential area within two miles of the SR-520 bridge termini would experience a negligible 0.3 percent increase in the prevalence of public sector employment once the toll is operational in 2012 until the end of the panel.

VIII.C.II. Toll Estimation, Comparison Group II

Relative to the estimated increase in employment density of 453 in tracts within two miles of the SR-520 bridge termini in the anticipatory specification (see Table 19) and 385 in the contemporaneous specification (see Table 20), firms were much less responsive to the operation of the toll in the broader boundaries as dictated by the Comparison Group II criterion: employment density increased by 84 and by 126 jobs per square mile in tracts within 1.5 miles of a ramp within five miles of the SR-520 termini within the anticipatory and contemporaneous models, respectively. Thus, results corresponding to the Comparison Group II measurement of proximity are available in the Appendix (see Table 56 through Table 61) and only a cursory discussion is included here. The toll has no measured impact on the prevalence of public sector employment within the Comparison Group II boundaries.

Contrary to the Comparison Group I estimation, the impact from the toll within the boundaries of interest are larger in the contemporaneous specification than in the anticipatory specification: *Toll Operational X Proximity 520* in Table 59 indicates a tract with 100 percent of its nonresidential area within the Comparison Group II boundaries would experience an increase in employment density of 126 jobs per square mile between 2012 and 2014, whereas *Toll Anticipatory Wgt. X Proximity 520* in Table 56 indicates the same tract would experience an increase in employment density of approximately 84 jobs per square mile from 2009 through 2014. The lower predicted increase in jobs from 2009 through 2014 in the anticipatory model versus the predicted increase in jobs from 2012 through 2014 suggests there was an outflow of employment from the Comparison Group II boundaries from 2009 through 2011. Employers may have anticipated burdens associated with locating near the tolled freeway prior to the toll's operation and, when these issues did not come to fruition, may have decided to relocate to the area. As in all prior estimations, the coefficient estimates presented are likely overestimates, although the results are likely closer to any actual realized increases due to Comparison Group II dominating a large swath of the study area and completely encompassing many tracts: 149 tracts adhere to the SR-520 Comparison Group II criterion, with the average nonresidential percentage being 85 percent and the minimum and maximum being 5 percent and 100 percent, respectively. This implies the average tract with any nonresidential area within the Comparison Group II boundaries may have experienced an increase in employment of 71 to 107 jobs per square mile.

VIII.D. Combined Estimation

Tables 21 and 22 display results from the combined anticipatory and contemporaneous models estimating both the light rail and toll's impact using the Comparison Group I definition of bridge proximity. The results below are very similar to the earlier anticipatory and contemporaneous results discussed, providing an additional robustness check. Results pertaining to the combined models using the Comparison Group II definition of proximity are available in Table 62 and Table 63 within the Appendix.

Table 21 displays the results from the combined anticipatory estimation of the two transit interventions' impact on employment density. The estimated coefficients realize a large increase in the magnitude of *Δ Anticipatory X New X Qtr-Mile,* a very slight increase in the magnitude of *Δ Toll Anticipatory Wgt. X Proximity 520* and a decrease in the magnitude of *Δ Anticipatory X Retro X Qtr-Mile* relative to their solitary counterparts in Table 17 and Table 19. Table 21 predicts a tract with 100 percent of nonresidential area within a ¼ mile of a retrofit station would lose 24,463 jobs from 2004 through 2010, and a tract with 100 percent of nonresidential area within a ¼ mile of a new station would lose 806 jobs over the same period. Once the average spatial relationship between the station tracts and the

Table 21 – Effect of Light Rail and Toll on Employment Characteristics, Combined Anticipatory Model, Comparison Group I Proximity Measurement

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public Jobs
Independent Variable		
Δ Lag Employment Density	-0.0389**	2.79e-08
	(0.0177)	(3.16e-07)
Δ Lag Black	43.96	-0.240
	(12,032)	(0.217)
Δ Age	2.647	-0.000840
	(157.9)	(0.00282)
Δ Education	-868.8	-0.0243
	(1,330)	(0.0238)
Δ Lag Income	0.000646	1.38e-07
	(0.00787)	(1.41e-07)
Δ Lag Unemployment	-5,647**	0.0470
	(2,664)	(0.0476)
Δ Lag Poverty	-1,700	0.0339
	(1,696)	(0.0303)
Δ Commute Length	-460.2	0.0163
	(1,165)	(0.0208)
Δ Pct. Utilizing Public Transit	-2,550	0.0154
	(1,739)	(0.0311)
Δ Home Price	-0.000194*	2.25e-09
	(0.000102)	(1.82e-09)
Initial value	0.0165***	-0.0222***
	(0.00280)	(0.00543)
Distance to CBD	5.266	5.87e-05
	(13.89)	(0.000247)
Distance to freeway	7.227	-0.000538
	(32.10)	(0.000572)
Percent Commuting to CBD	859.7	0.0175
	(977.3)	(0.0165)
Pct. Nonresidential	65.33	0.00142
	(111.9)	(0.00191)
Eastside	103.1	0.00114
	(96.56)	(0.00170)
Toll Anticipatory Weight	3.485	-0.00259*
	(74.67)	(0.00133)
Proximity 520	-380.0	-0.00453
	(250.9)	(0.00449)
Proximity I-90	-140.1	-0.00223
	(153.7)	(0.00275)
Toll Anticipatory Wgt. X Proximity 520	555.8	0.00459
	(373.3)	(0.00668)
Δ Anticipatory X Retro X Qtr-Mile	-24,463***	-0.0132
	(6,581)	(0.102)
Δ Anticipatory X New X Qtr-Mile	-805.7	-0.368***
	(4,612)	(0.0835)
Observations	3,159	3,159
Number of tract	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

tracts' total area is taken into account, this converts to a decline in employment of 7,584 and 185 for the average tract with any nonresidential area within ¼ mile of retrofit and new stations, respectively. Table 21 also predicts a tract with 100 percent of nonresidential area within two miles of the SR-520 termini would experience an increase in employment of 556 from 2008 through 2014. The actual expected increase in employment in a tract with any nonresidential area within two miles of the SR-520 termini is 334 jobs from 2008 through 2014.

The increase in the magnitudes of *Δ Anticipatory X New X Qtr-Mile and Δ Toll Anticipatory Wgt. X Proximity 520* may reflect the overlap between several new station areas and the SR-520 two-mile termini boundary on the west side of the lake (see Figure 16 in the Appendix). In the anticipatory model, these tracts receive the 'treatment' of the light rail from 2012-2014 and receive the 'treatment' of the toll from 2009 through 2014. These two influences simultaneously may serve to allow the model to more precisely attribute job shifting to transportation infrastructure changes.

The combined anticipatory estimation regarding the prevalence of public sector employment results in a decrease in *Δ Anticipatory X New X Qtr-Mile* and an increase in *Δ Anticipatory X Retro X Qtr-Mile* relative to their estimated values in Table 17. *Toll Anticipatory Wgt. X Proximity 520* is negligible in both the combined model and Table 19. Since the combined model estimates a larger decrease in total employment surrounding new stations than the original model in Table 17, the decrease in the impact of the light rail on the prevalence of public sector employment surrounding new stations may be partially attributable to this resulting smaller base number of jobs. Likewise, since the combined

Table 22 – Effect of Light Rail and Toll on Employment Characteristics, Combined Contemporaneous Model, Comparison Group I Proximity Measurement

	Dependent Variable	
	Δ Employment Density	Δ Pct Public
Independent Variables		
Δ Lag Employment Density	-0.0720***	1.32e-07
	(0.0176)	(3.11e-07)
Δ Lag Black	475.0	-0.208
	(11,807)	(0.212)
Δ Age	53.69	-0.000395
	(153.7)	(0.00273)
Δ Education	-807.6	-0.0158
	(1,303)	(0.0232)
Δ Lag Income	0.000700	1.24e-07
	(0.00771)	(1.37e-07)
Δ Lag Unemployment	-5,964**	0.0411
	(2,611)	(0.0465)
Δ Lag Poverty	-1,598	0.0264
	(1,662)	(0.0296)
Δ Home Price	-0.000205**	2.23e-09
	(0.000100)	(1.79e-09)
Distance to CBD	4.959	2.95e-05
	(13.58)	(0.000239)
Distance to Freeway	7.362	-0.000493
	(31.47)	(0.000558)
Percent Commuting to CBD	872.5	0.0116
	(955.9)	(0.0156)
Eastside	103.4	0.000815
	(94.66)	(0.00165)
Δ Commute Length	-309.8	0.0145
	(1,144)	(0.0203)
Δ Pct. Utilizing Public Transit	-1,489	0.00138
	(1,707)	(0.0304)
Initial Value	0.0177***	-0.0189***
	(0.00243)	(0.00525)
Pct. Nonresidential	66.28	0.000341
	(108.6)	(0.00184)
Toll Operational	40.25	-0.00218*
	(65.78)	(0.00117)
Proximity 520	-278.1	-0.00296
	(197.2)	(0.00351)
Proximity I-90	-131.6	-0.000608
	(150.8)	(0.00268)
Toll Operational X Proximity 520	505.0	0.00181
	(331.7)	(0.00590)
Δ Station Operational X Retro X Qtr-Mile	-15,721***	0.0380
	(1,350)	(0.0234)
Δ Station Operational X New X Qtr-Mile	-1,298	-0.355***
	(1,506)	(0.0269)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

anticipatory model estimates a smaller decrease in total employment surrounding retrofit stations, any coinciding decrease in the number of public sector jobs will be larger relative to this smaller base.

Table 22 presents the results of the contemporaneous combined estimation. Relative to the anticipatory combined estimation results above, the estimated coefficients move in the same direction as the previously discussed changes relative to Table 18 (pertaining to the light rail) and Table 20 (pertaining to the toll). *Δ Station Operational X New X Qtr-Mile* in Table 22 predicts a tract with 100 percent of nonresidential area within a ¼ mile of a new station would experience a decrease in employment density of 1,298 jobs per square mile (relative to a decrease of 1,439 jobs per square mile in Table 18), while *Δ Station Operational X Retro X Qtr-Mile* predicts a tract with 100 percent of its nonresidential area within a ¼ mile of a retrofit station would experience a decline in jobs of 15,721 (relative to a decrease of 15,754 jobs in Table 18). As in Table 21, the combined estimation alters the toll's positive impact on employment density, with *Toll Operational X Proximity 520* increasing from 385 in Table 20 to 505 in Table 22.

The estimated light rail coefficients in Table 22 also decrease in magnitude relative to their counterparts in Table 18 in regards to the light rail's impact on public sector employment. With Table 22 predicting both a smaller total decrease in employment and a smaller percentage decline in the prevalence of public sector employment around both station types in the system's first year of operation, one obvious implication is that the additional job loss predicted in Table 18 comes from the government sector. The toll's negligible impact on the prevalence of public sector employment does not change once the light rail is controlled for.

IX. Conclusion

Both transit interventions appear to be impacting the growth of population and employment within their associated vicinities. Neighborhoods adjacent to light rail stations have experienced increases in population densification, decreases in employment density and a shift in employment composition in favor of the private sector. The net increase in both population and employment density within vicinities with easy access to the tolled facilities indicates households and firms perceive the area as more accessible post toll-operation, potentially due to the decrease in the time allowance in accessing the area. Table 23 and Table 24 below reiterate the effect of the transit interventions across the six dependent variables using the combined anticipatory model and the Comparison Group I definition of bridge proximity (Table 15 and Table 21). Recall that the estimated actual impacts are lower than the figures displayed in the tables below since no tracts are entirely contained within a ¼ mile of either station or within two miles of the SR-520 termini (see discussion pertaining to Table 15 and Table 21 for estimated actual impacts). I choose to leave the reader with the results from the combined anticipatory model since the estimates represent the accumulated response to the transit interventions when accounted for concurrently. I choose the Comparison Group I definition of bridge proximity as this area appears to delineate a more responsive population since a greater proportion of all adjusted occurred prior to the tolls operation relative to the Comparison Group II measurement.

The results presented within this work coincide with the literature's general conclusion that light rail transit can positively impact regional density if a region is experiencing both economic and population growth and complementary urban policies are utilized to direct growth in the intended locations. As the light rail system continues to expand across the

Table 23 - Effect of the Light Rail and Toll on Population and Demographics, Combined Anticipatory Model, Comparison Group I Measurement

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Lag Black	Δ Age
Independent Variable				
Toll-Weight X Proximity 520	47.17	-21.46	0.00343***	0.269***
	(40.44)	(26.91)	(0.000454)	(0.0365)
Δ Anticipatory X Retro X Qtr-Mile	1,657**	1,048**	-0.00311	-1.124*
	(731.9)	(466.4)	(0.00849)	(0.678)
Δ Anticipatory X New X Qtr-Mile	2,797**	931.2	-0.0176	1.908*
	(1,121)	(706.9)	(0.0126)	(1.002)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

region, additional facilities' degrees of accessibility will be positively impacted, potentially leading to increases in ridership and a further increase in densification around stations. Beyond the system's increased future accessibility, the *Sound Transit 3* initiative requiring the construction of affordable housing facilities around future stations could further accelerate the growth in population density around stations.

Table 24 – Effect of Light Rail and Toll on Employment Characteristics, Combined Anticipatory Model, Comparison Group I Proximity Measurement

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public Jobs
Independent Variable		
Toll Anticipatory Wgt. X Proximity 520	555.8	0.00459
	(373.3)	(0.00668)
Δ Anticipatory X Retro X Qtr-Mile	-24,463***	-0.0132
	(6,581)	(0.102)
Δ Anticipatory X New X Qtr-Mile	-805.7	-0.368***
	(4,612)	(0.0835)
Observations	3,159	3,159
Number of tract	351	351

The City has designated light rail stations as the centroids of urban communities across the region through strategic planning initiatives directing growth and investment towards mass transit facilities. Living near mass transit allows for increased access to education, employment and recreational opportunities, and decreases the cost of living associated with owning a vehicle. Increased density around mass transit facilities also provides positive externalities for the region as a whole, as corridors become less congested, sprawl is reduced and fewer emissions are released.

Although several City officials have suggested that the opportunity for growth may not have been fully exploited around the system's earliest stations, this recognition suggests that future planning is expected to achieve more substantial changes in the urban form than the stations included within this study. However, it is difficult to predict the impact of the light rail system on potential displacement of the City's urban poor. If low-income individuals near stations have experienced difficulty in finding and maintaining employment due to a lack of reliable transportation, then the initiation of the light rail system may provide an impetus for these individuals to lift themselves out of poverty. This benefit of increased accessibility will inevitability increase demand for station locations, potentially leading to higher rental prices and displacement. Through public funds and private developers seeking up-zoning, the City hopes to minimize displacement of prior communities around light rail stations through the continued addition of affordable units. However, unless the affordable units constructed are able to house the existing low-income population, the displacement of current residents is possible.

Although the determination of total welfare gains and losses due to the light rail system is outside the scope of this work, the increases in density associated with station locations are highly suggestive of increases in rental rates per square foot. Displacement may also not be homogenous across the system's stations: through isolating stations with initial resident populations that are low-income and also allowing for differing displacement rates contingent on the year of commencement of a station's construction, an understanding of the adjustments to the urban form around individual stations may be gleaned. Once additional stations are operational, a study investigating the impact of the system on gentrification and any resulting displacement may be justified.

The tolling of the SR-520 created a natural experiment in which to evaluate the impact of the toll against the alternate un-tolled facility. Although the two definitions of bridge proximity relative to the SR-520 produce results of different magnitudes, it remains unclear as to the boundary that would best delineate the households and firms most responsive to the toll. A future analysis using flexible boundaries around the SR-520 bridge termini could determine the locations that have experienced the most positive and negative growth and could inform policy remedies if it is determined that certain subgroups are disproportionately impacted by the toll. Additionally, an analysis of the change in the average income within the SR-520 impact areas could determine if the supposition discussed within this work is correct, namely, that the increase in population within the SR-520 impact areas is due to wealthy individuals seeking to relocate to the area to avoid congestion. Within the next decade, the light rail will cross Lake Washington along the I-90 bridge, further impacting the traffic volumes along both bridges traversing the lake. As the region continues to grow, the implementation of policies directed at achieving residential and commercial growth in the appropriate vicinities could both generate demand for public transit and discourage the utilization of a personal vehicle.

Appendix- Figures

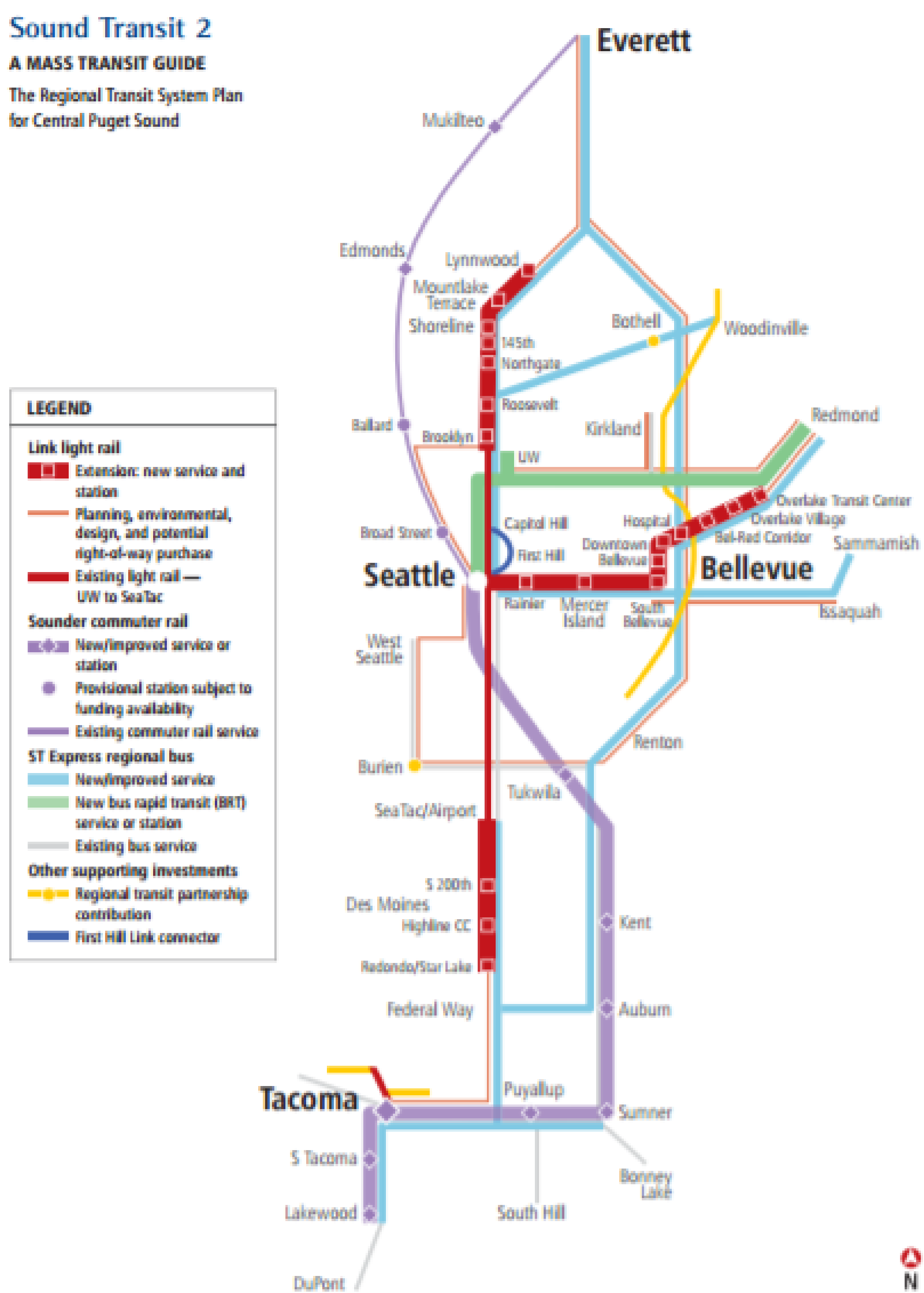
Figure 10 – The Seattle Area’s Light Rail System – Phase I

Source: Sound Transit, 1995

Figure 11 – The Seattle Area's Light Rail System – Sound Move

Source: Sound Transit, 1996

Figure 12 -The Seattle Area's Light Rail System – Sound Transit 2



Source: Sound Transit, 2008

Figure 13 – The Seattle Area's Light Rail System – Sound Transit 3

Source: Sound Transit, 2016

Figure 14 – Anticipatory Weights Applied to Original Station Interaction Terms

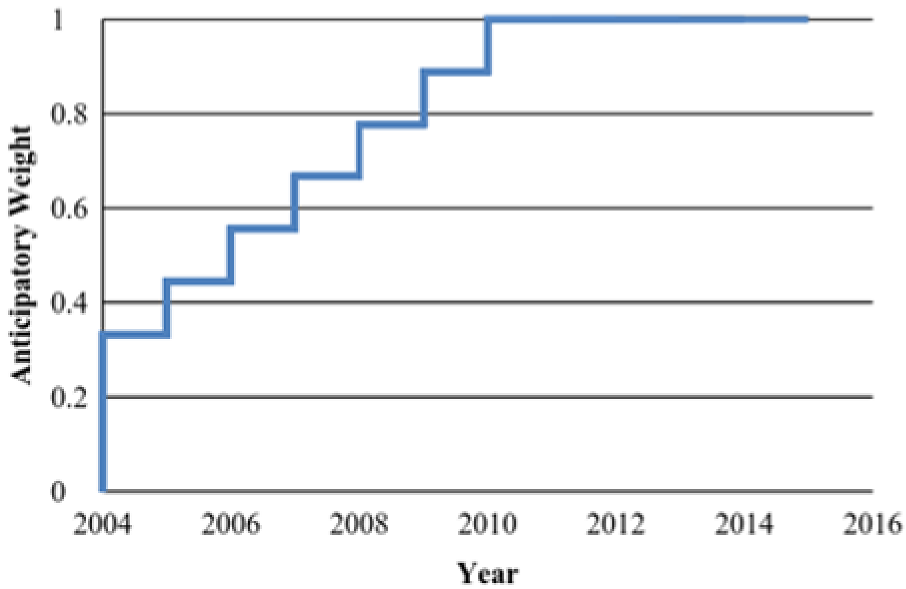


Figure 15 – Anticipatory Toll Weights

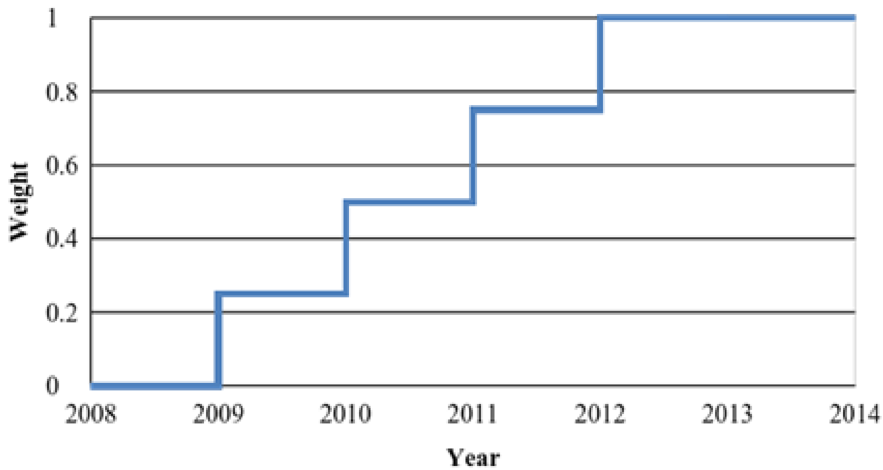


Figure 16 - Overlap of Comparison Group I Boundary and Quarter-Mile Boundary around Light Rail Stations Included in Anticipatory Model

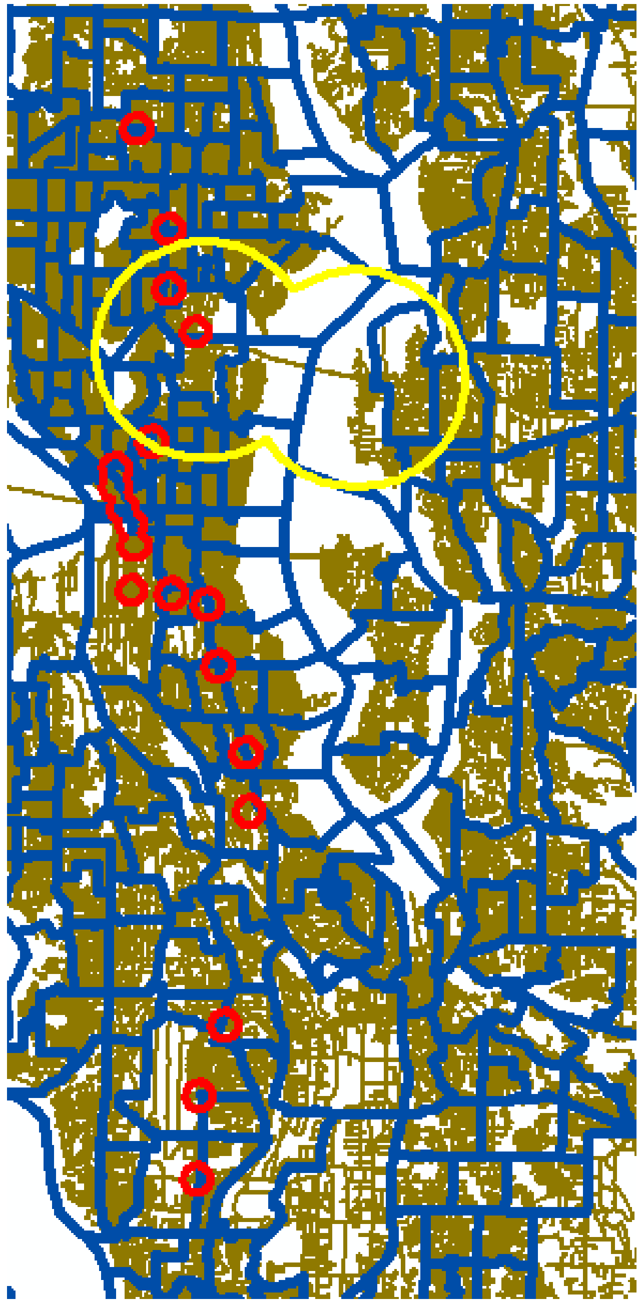


Figure 17 - Overlap of Comparison Group I Boundary and Quarter-Mile Boundary around Light Rail Stations Included in Contemporaneous Model

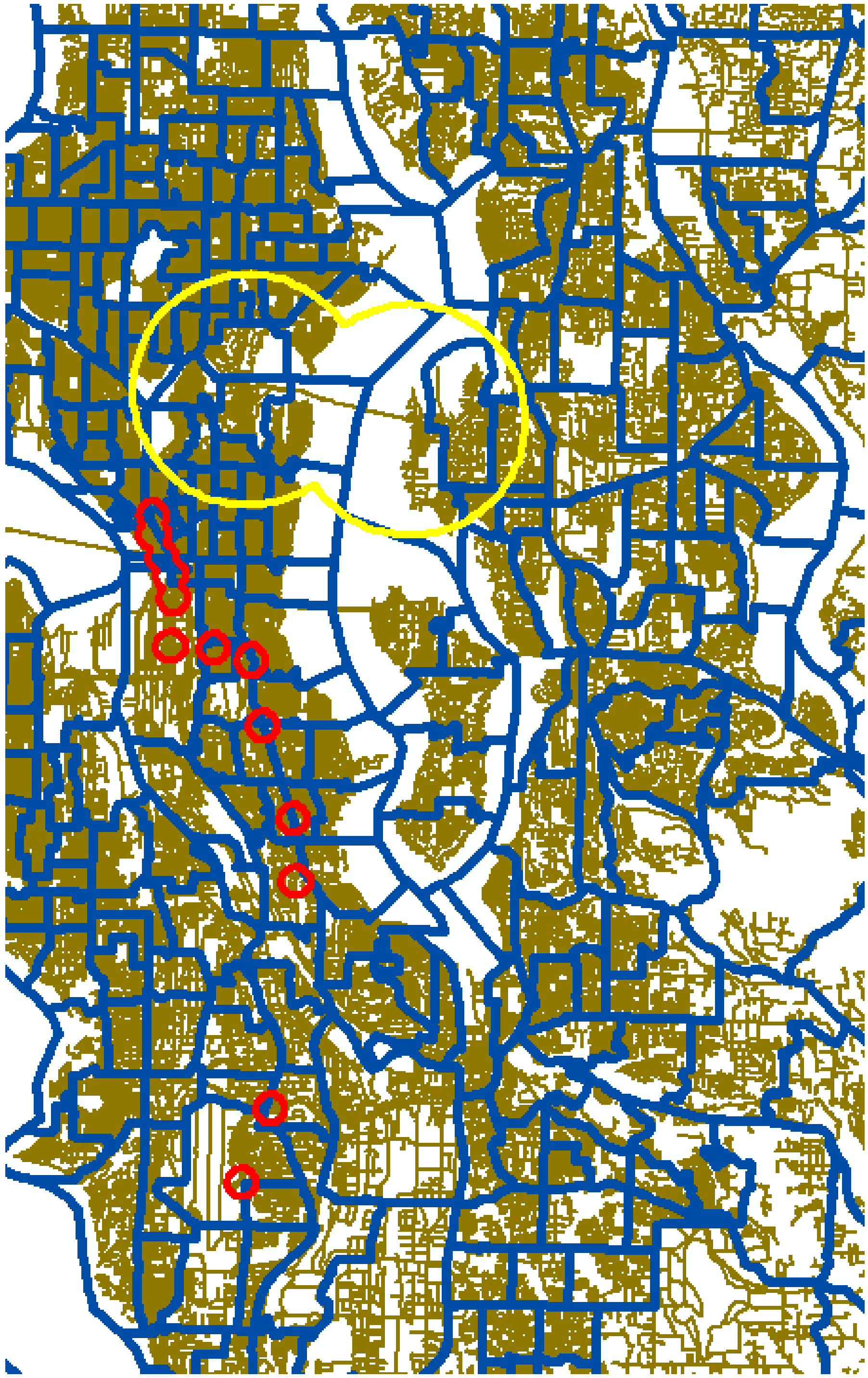


Figure 18 - Overlap of Comparison Group II Boundary and Quarter-Mile Boundary around Light Rail Stations Included in Anticipatory Model

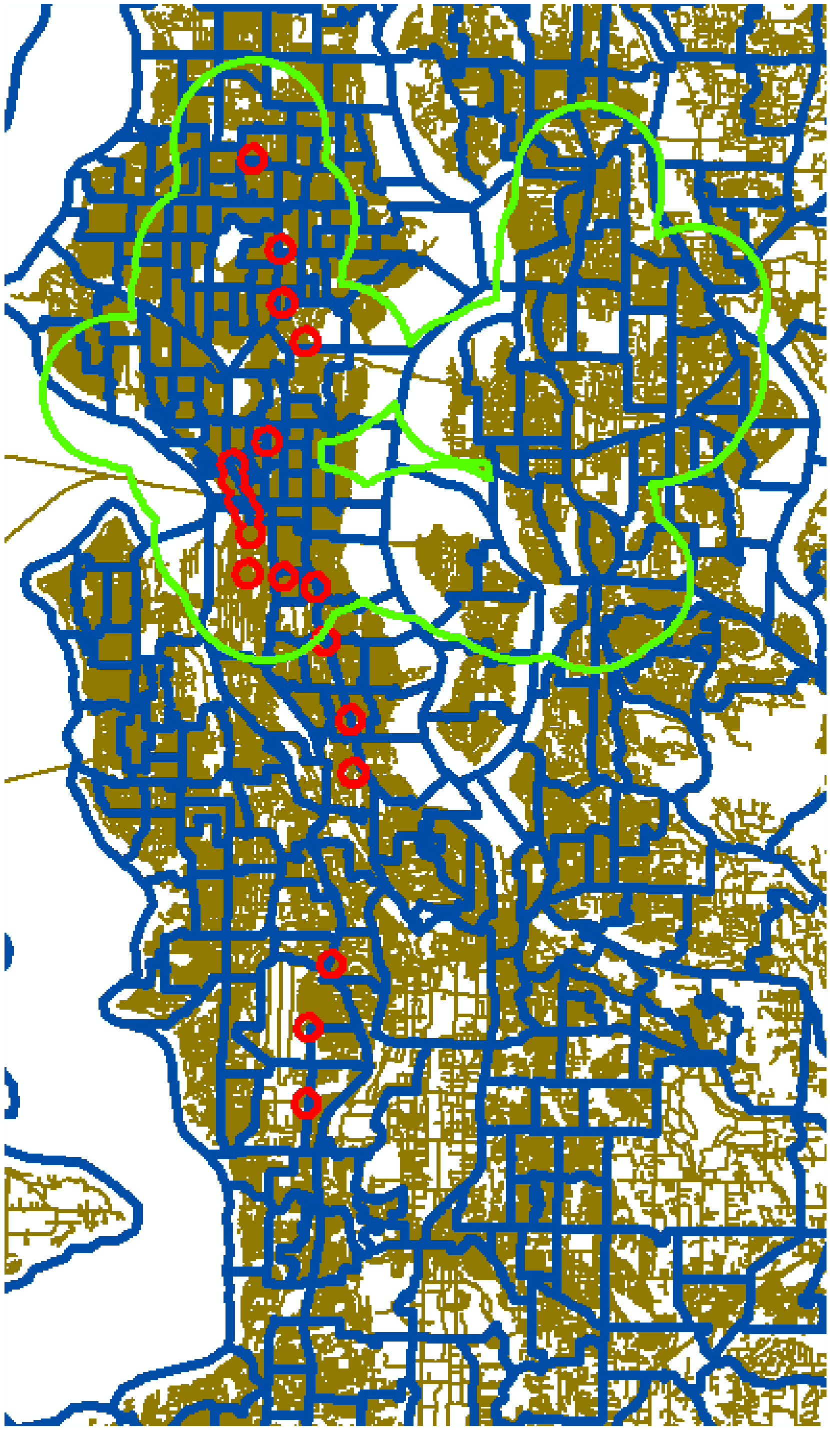


Figure 19 - Overlap of Comparison Group II Boundary and Quarter-Mile Boundary around Light Rail Stations Included in Contemporaneous Model

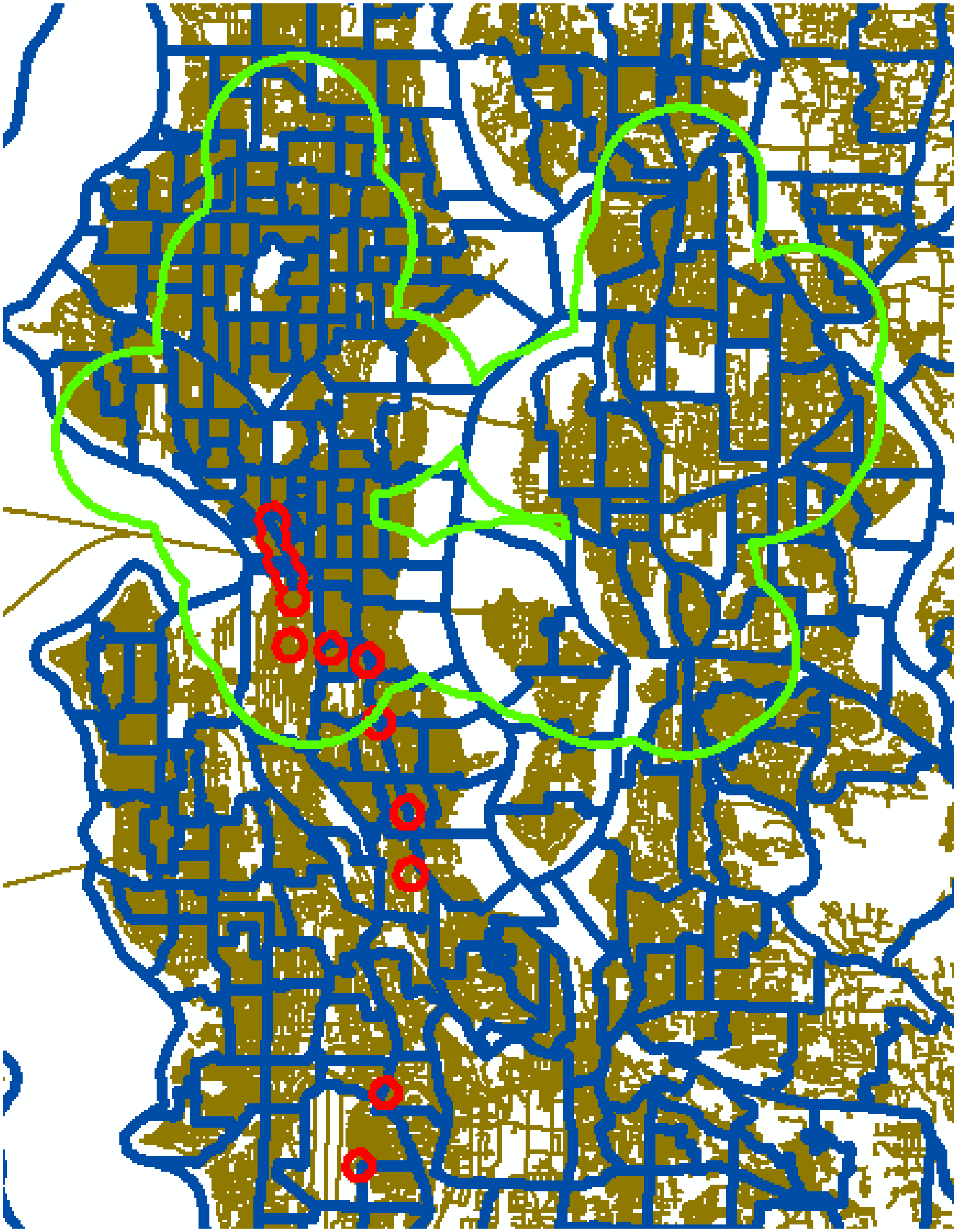


Figure 20– Annual Total Population Within ½ Mile of All Stations Within Anticipatory Model by Station Type

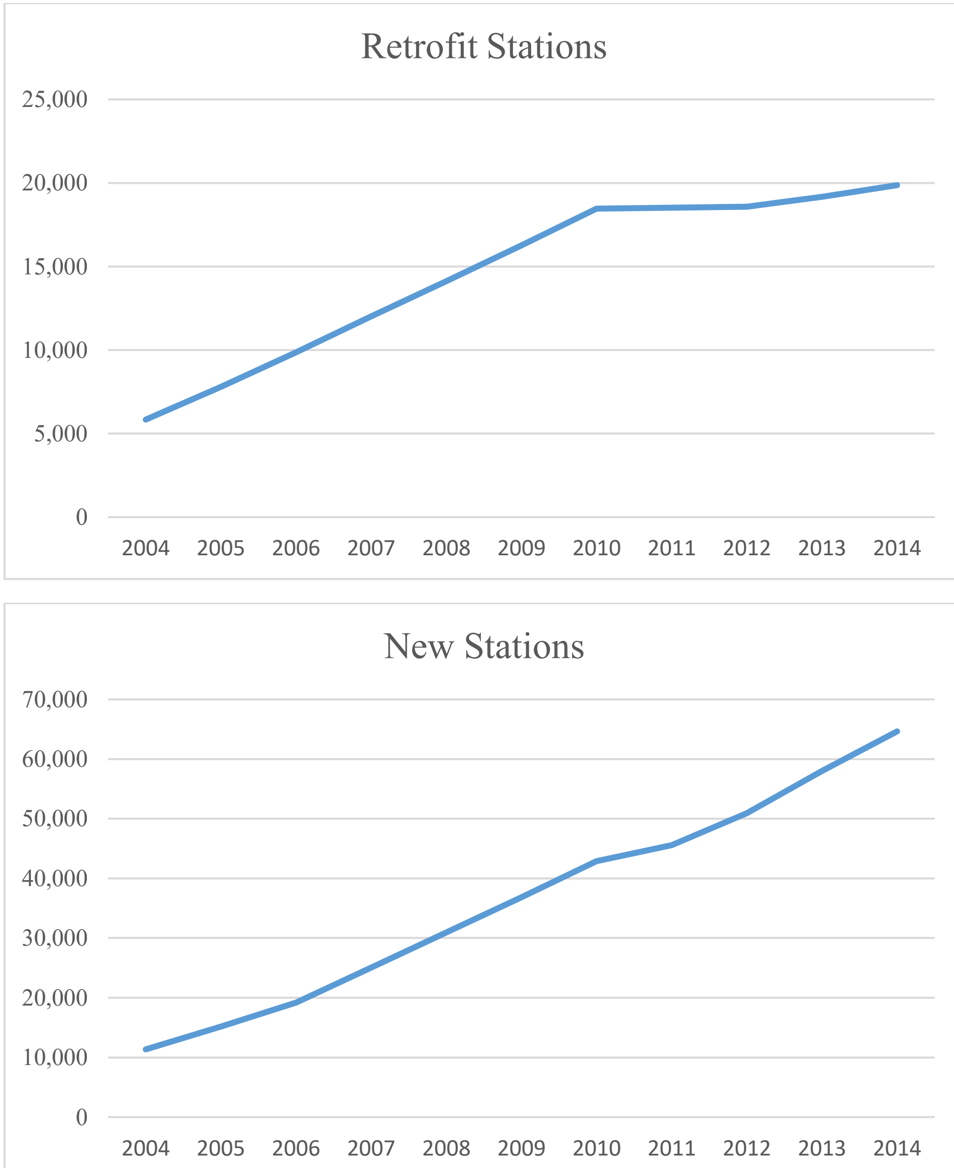
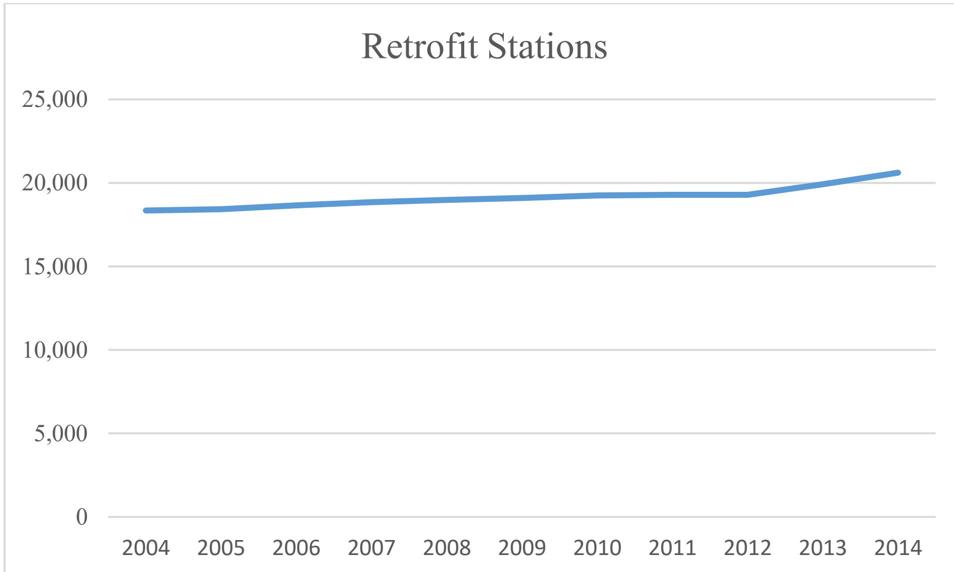


Figure 21 – Annual Total Population within ½ Mile of All Stations within Contemporaneous Model by Station Type



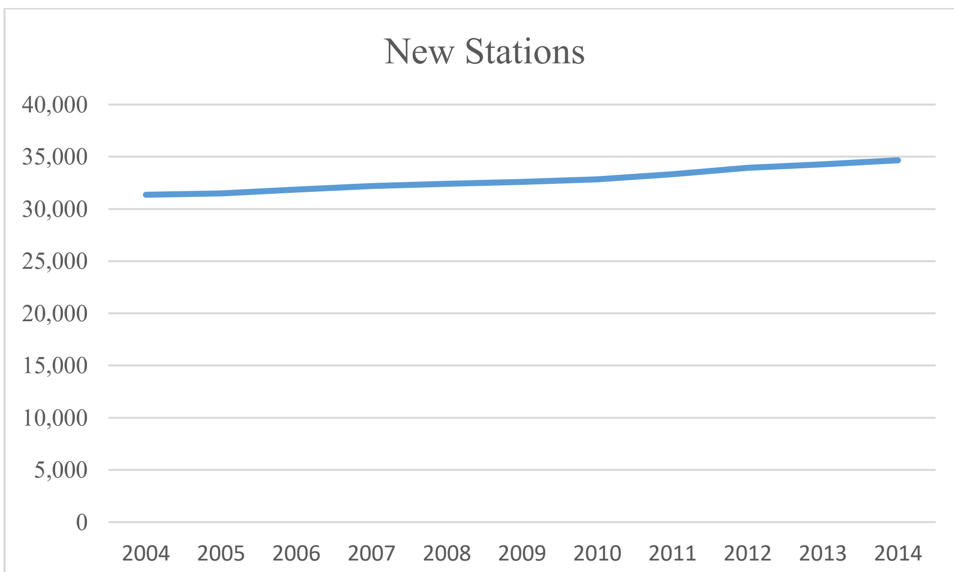
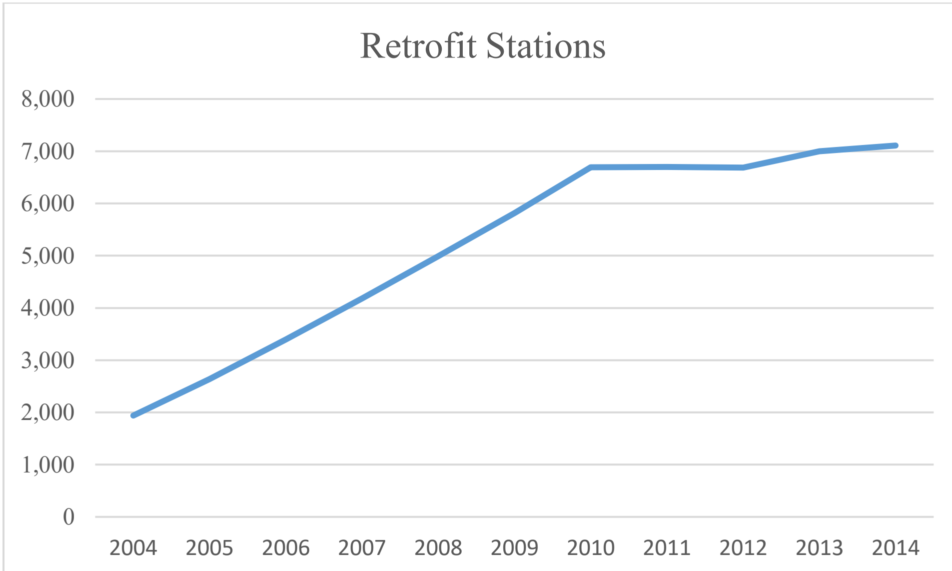


Figure 22 – Annual Total Population within a ¼ Mile of All Stations within Anticipatory Model by Station Type



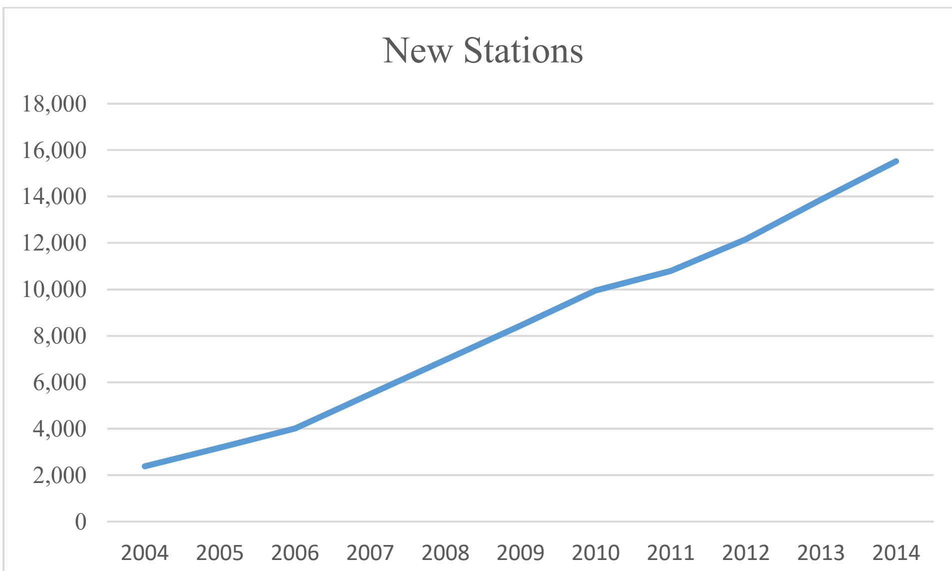


Figure 23 – Annual Total Population within a ¼ Mile of All Stations within Contemporaneous Model by Station Type

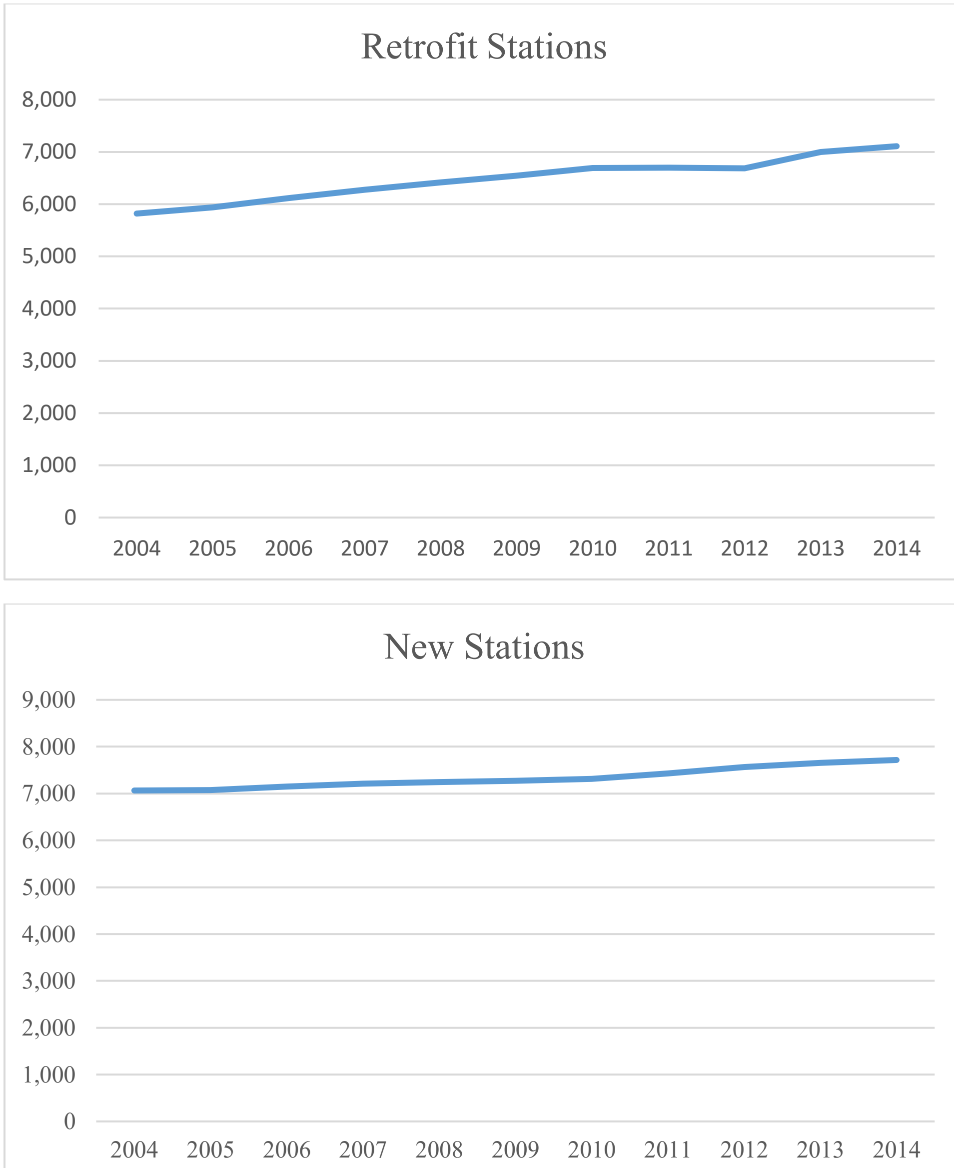
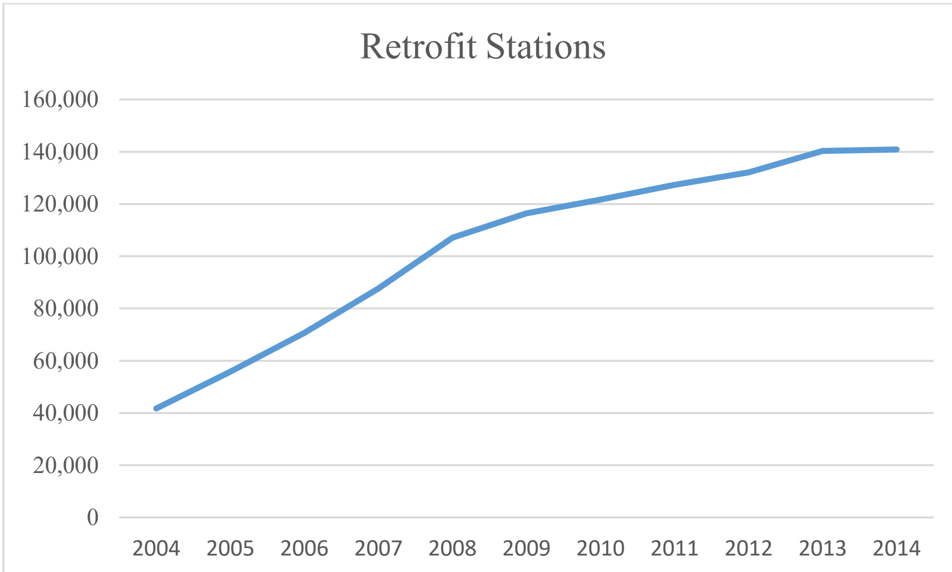


Figure 24 – Annual Total Employment within ½ Mile of All Stations within Anticipatory Model by Station Type



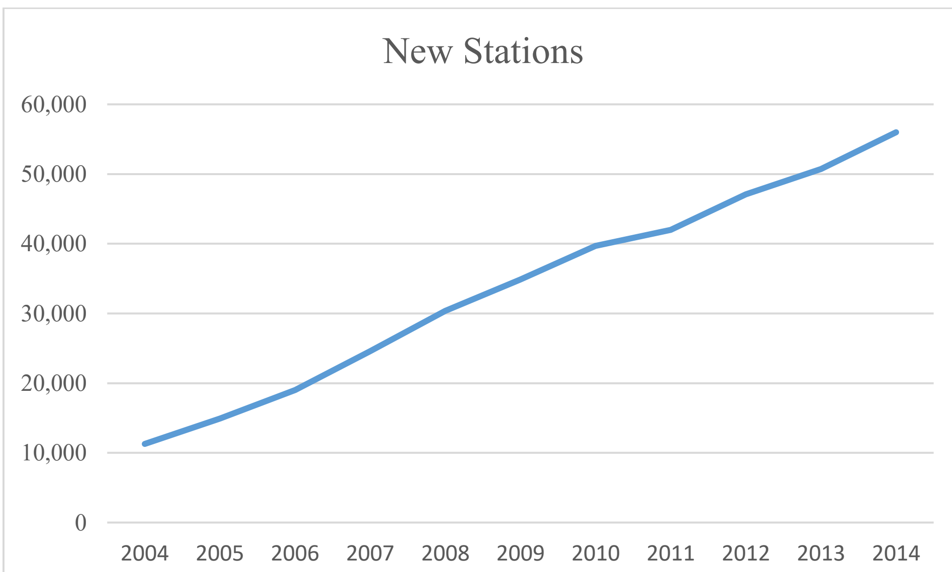


Figure 25 – Annual Total Employment within ½ Mile of All Stations within Contemporaneous Model by Station Type

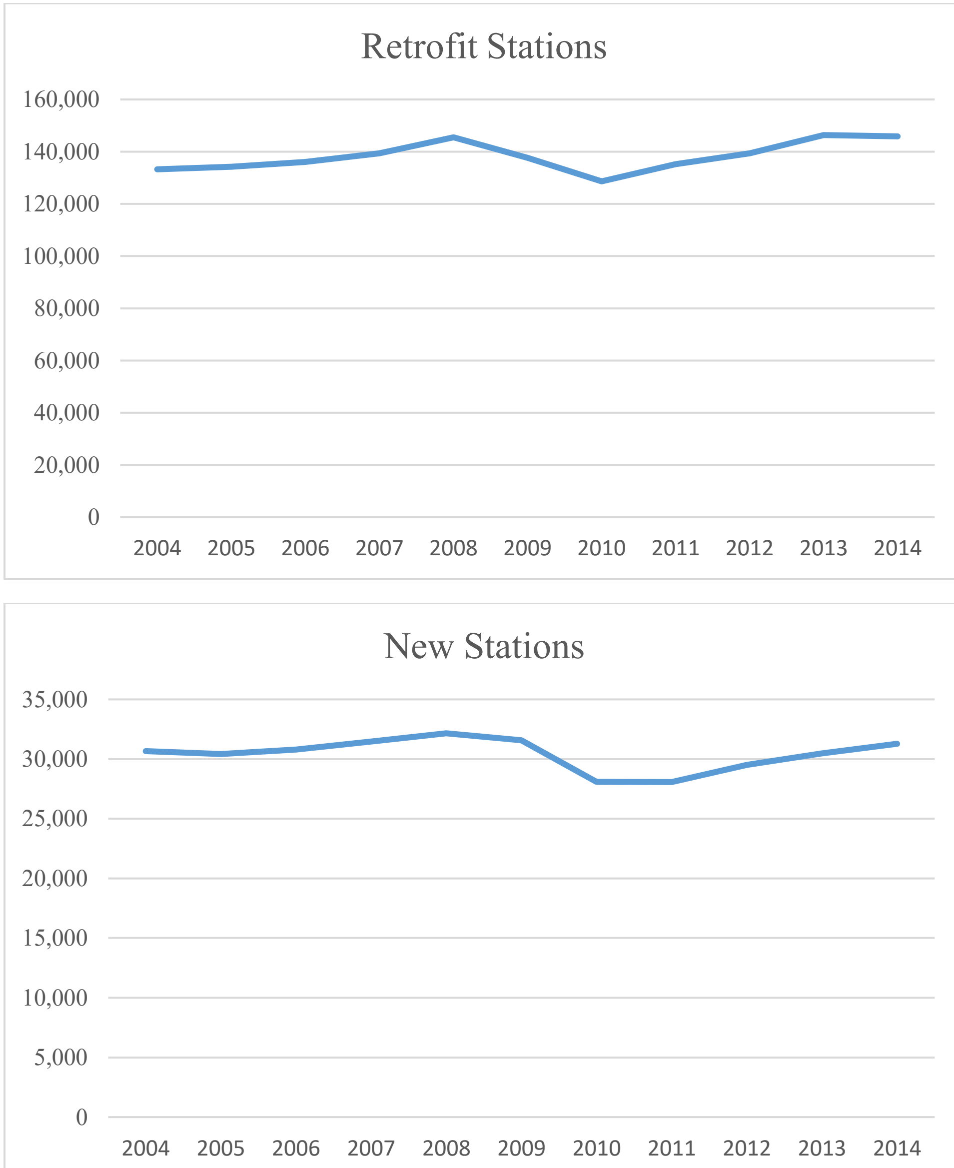
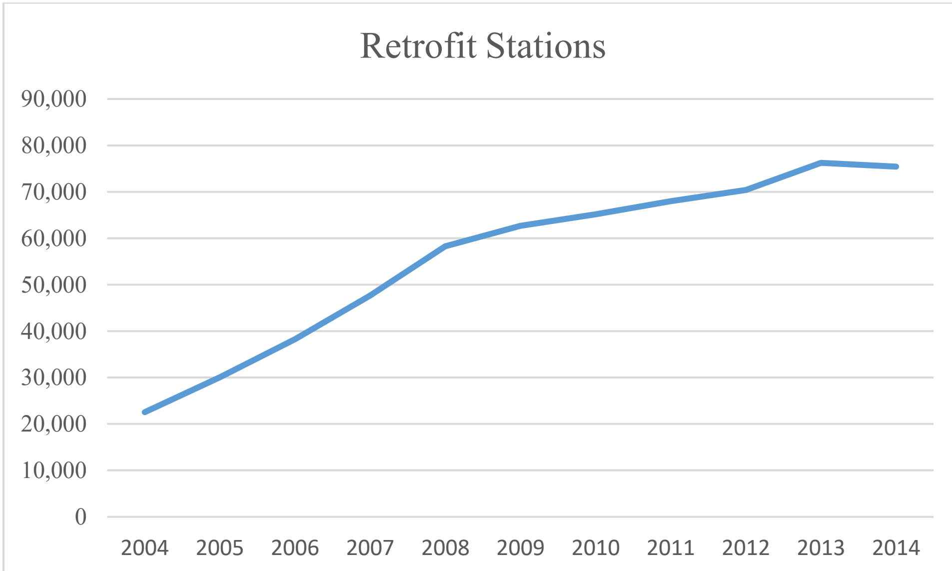


Figure 26– Annual Total Employment within a ¼ Mile of All Stations within Anticipatory Model by Station Type



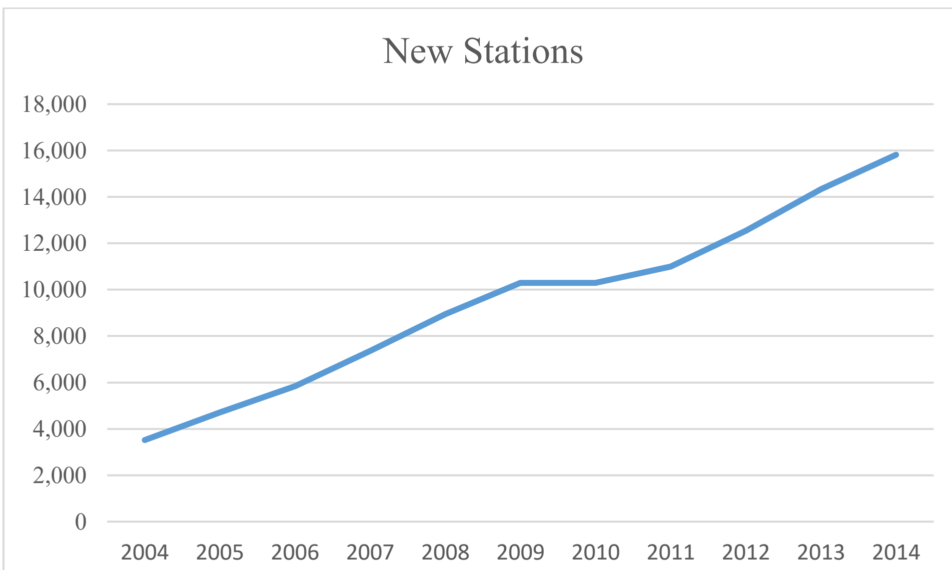
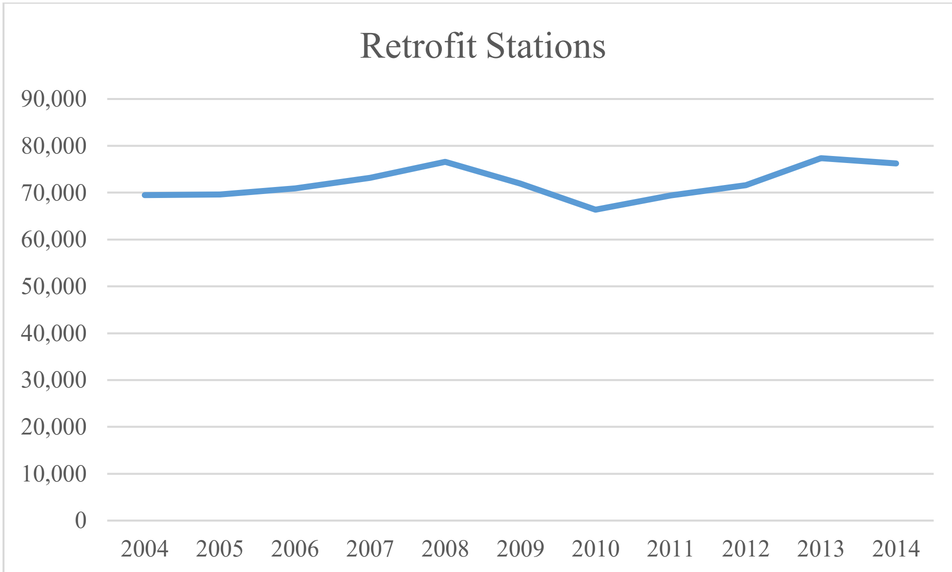
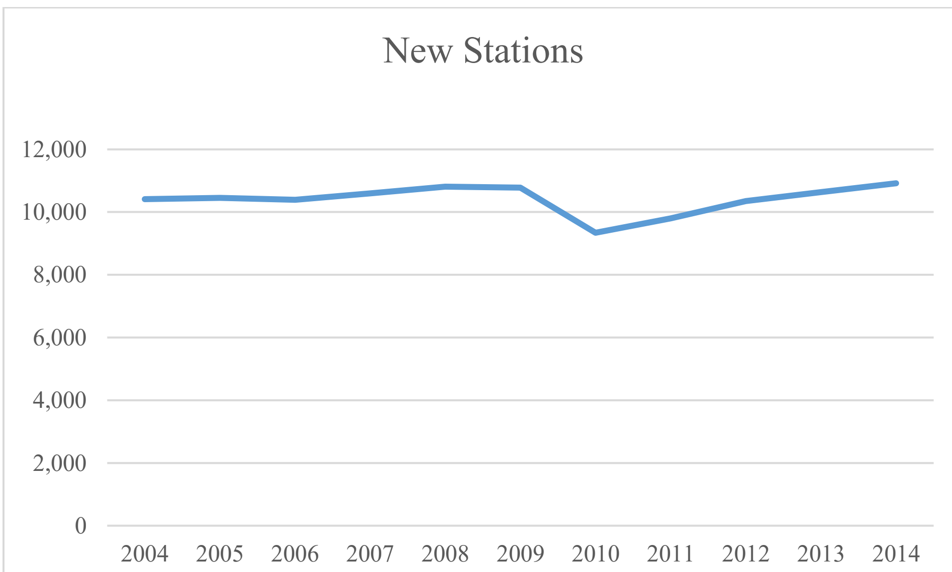


Figure 27 – Annual Total Employment within a ¼ Mile of All Stations within Contemporaneous Model by Station Type





Appendix – Tables

Table 25 - Effect of Light Rail on Population Characteristics, Anticipatory Model – Stratified by Presence of Tract within ½ mile of Station

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Pct. Black	Δ Age
Independent Variable				
Δ Lag Pct. Black	13,743**	2,025		-0.890
	(6,348)	(4,016)		(2.714)
Δ Age	-289.1***	-84.15	0.00166**	
	(106.4)	(68.96)	(0.000786)	
Δ Education	290.1	17.85	-0.00168	0.630**
	(704.4)	(464.0)	(0.00509)	(0.297)
Δ Lag Income	0.00618	0.00320	-2.20e-08	-6.82e-07
	(0.00599)	(0.00395)	(4.36e-08)	(2.54e-06)
Δ Lag Unemployment	412.6	-234.6	-0.0164	-0.512
	(1,444)	(960.7)	(0.0105)	(0.612)
Δ Lag Poverty	-580.7	-614.4	-0.000285	-0.0335
	(856.2)	(566.4)	(0.00620)	(0.364)
Δ Commute Length	1,397**	293.6	0.00330	0.156
	(706.1)	(468.6)	(0.00512)	(0.299)
Δ Pct. Utilizing Public Transit	8.003	272.9	-0.000581	0.505
	(901.7)	(597.0)	(0.00653)	(0.382)
Δ Home Price	8.17e-05*	5.22e-05	2.12e-10	-8.67e-09
	(4.89e-05)	(3.24e-05)	(3.55e-10)	(2.08e-08)
Initial value	0.00771**	0.00754***	-0.00474	-0.000184
	(0.00376)	(0.00285)	(0.00326)	(0.00408)
Distance to CBD	-27.63	-2.521	0.000483***	0.00649
	(19.06)	(9.984)	(0.000150)	(0.00847)
Distance to Freeway	10.95	-4.240	-0.000485	0.0705**
	(72.04)	(37.87)	(0.000680)	(0.0315)
Pct. Commuting to CBD	-191.5	758.5	0.000395	0.207
	(891.5)	(465.8)	(0.00706)	(0.401)
Pct. Residential	11.74	-39.16	-0.00221**	-0.0492
	(130.0)	(67.81)	(0.00104)	(0.0577)
Δ Anticipatory X Retro X Qtr- Mile	1,328	483.1	0.00381	-1.248*
	(1,656)	(1,016)	(0.0122)	(0.717)
Δ Anticipatory X New X Qtr-Mile	2,407	705.2	-0.00115	1.482
	(2,540)	(1,535)	(0.0181)	(1.050)
Observations	504	504	504	504
Number of tracts	56	56	56	56

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 26 - Effect of Light Rail on Population Characteristics, Contemporaneous Model – Stratified by Presence of Tract within ½ mile of Station

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Pct. Black	Δ Age
Independent Variable				
Δ Lag Pct. Black	14,928**	2,255		-5.229*
	(7,547)	(5,071)		(3.047)
Δ Age	-517.7***	-194.8*	0.00120	
	(153.2)	(103.7)	(0.00131)	
Δ Education	1,869*	807.6	-0.00420	0.750*
	(1,129)	(775.6)	(0.00950)	(0.447)
Δ Lag Income	0.0124	0.00605	-5.65e-08	-3.55e-06
	(0.00906)	(0.00624)	(7.71e-08)	(3.60e-06)
Δ Lag Unemployment	-2,150	-1,489	-0.00937	-1.852**
	(1,948)	(1,344)	(0.0166)	(0.767)
Δ Lag Poverty	-1,843	-935.6	-0.00234	-0.0500
	(1,156)	(797.9)	(0.00981)	(0.460)
Δ Commute Length	1,387	67.31	0.00224	-0.00154
	(950.2)	(655.2)	(0.00808)	(0.379)
Δ Pct. Utilizing Public Transit	654.7	708.4	-0.0107	0.709
	(1,235)	(849.9)	(0.0105)	(0.491)
Δ Home Price	0.000262***	0.000192***	-5.18e-10	-1.15e-08
	(9.88e-05)	(6.82e-05)	(8.41e-10)	(3.93e-08)
Initial value	0.00115	0.00385	-0.0109**	-0.00544
	(0.00511)	(0.00392)	(0.00526)	(0.00578)
Distance to CBD	-15.43	5.765	0.000852***	0.00229
	(30.90)	(18.24)	(0.000240)	(0.0143)
Distance to Freeway	-69.97	-56.18	-7.14e-05	0.0418
	(91.26)	(54.40)	(0.000839)	(0.0418)
Pct. Commuting to CBD	897.0	1,207	0.00830	-0.0729
	(1,351)	(765.1)	(0.00994)	(0.579)
Pct. Residential	348.4*	118.1	-0.00142	0.0285
	(189.3)	(111.4)	(0.00152)	(0.0901)
Δ Station Operational X Retro X Qtr-Mile	103.0	93.07	0.000405	0.0414
	(356.3)	(244.6)	(0.00303)	(0.142)
Δ Station Operational X New X Qtr-Mile	-185.5	-105.9	-0.00353	0.786**
	(921.3)	(635.5)	(0.00785)	(0.364)
Observations	279	279	279	279
Number of tracts	31	31	31	31

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 27 - Effect of Light Rail on Population Characteristics, Anticipatory Model and ½ Mile Proximity Measurement

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Pct. Black	Δ Age
Independent Variable				
Δ Lag Pct. Black	5,005***	591.6		-0.535
	(1,518)	(974.0)		(1.418)
Δ Age	-164.3***	-87.59***	0.000298	
	(18.93)	(12.32)	(0.000220)	
Δ Education	204.8	105.4	-0.000600	0.174
	(147.1)	(97.27)	(0.00168)	(0.137)
Δ Lag Income	0.00224**	0.00125**	-6.24e-10	2.12e-06***
	(0.000871)	(0.000577)	(9.97e-09)	(8.09e-07)
Δ Lag Unemployment	230.3	-33.20	-0.00523	0.425
	(292.8)	(194.1)	(0.00335)	(0.272)
Δ Lag Poverty	-410.0**	-347.3***	-0.000778	-0.498***
	(186.1)	(123.3)	(0.00213)	(0.173)
Δ Commute Length	112.0	-23.26	0.00195	-0.127
	(126.5)	(83.84)	(0.00145)	(0.118)
Δ Pct. Utilizing Public Transit	128.5	111.9	-0.000827	-0.00339
	(191.3)	(126.8)	(0.00219)	(0.178)
Δ Home Price	2.59e-05**	1.78e-05**	2.03e-10	-2.63e-09
	(1.09e-05)	(7.25e-06)	(1.25e-10)	(1.02e-08)
Initial value	0.0115***	0.0112***	-0.00306***	-0.00795***
	(0.00141)	(0.00120)	(0.00110)	(0.00152)
Distance to CBD	-1.303	0.932	0.000141***	0.0106***
	(2.399)	(1.381)	(3.12e-05)	(0.00231)
Distance to Freeway	-2.235	-3.182	-0.00041***	0.0215***
	(6.187)	(3.541)	(7.99e-05)	(0.00581)
Pct. Commuting to CBD	240.5	312.5***	-0.000535	0.304**
	(165.9)	(94.99)	(0.00205)	(0.147)
Pct. Residential	-101.6***	-66.22***	-0.000105	-0.0574***
	(20.52)	(11.67)	(0.000266)	(0.0194)
Δ Anticipatory X Retro X Hlf-Mile	-1,974***	633.9**	-0.0138***	-0.268
	(453.0)	(290.4)	(0.00529)	(0.422)
Δ Anticipatory X New X Hlf-Mile	80.48	-18.22	0.00686*	0.395
	(333.3)	(213.3)	(0.00382)	(0.303)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 28 - Effect of Light Rail on Population Characteristics, Contemporaneous Model and ½ Mile Proximity Measurement

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Pct. Black	Δ Age
Independent Variable				
Δ Lag Pct. Black	5,169***	571.2		-0.515
	(1,524)	(975.1)		(1.415)
Δ Age	-160.9***	-88.65***	0.000320	
	(19.00)	(12.33)	(0.000220)	
Δ Education	203.9	106.4	-0.000543	0.177
	(147.3)	(97.24)	(0.00169)	(0.137)
Δ Lag Income	0.00227***	0.00124**	-4.99e-10	2.14e-06***
	(0.000872)	(0.000577)	(9.99e-09)	(8.08e-07)
Δ Lag Unemployment	233.3	-32.49	-0.00520	0.434
	(293.1)	(194.0)	(0.00336)	(0.272)
Δ Lag Poverty	-399.6**	-350.2***	-0.000665	-0.494***
	(186.3)	(123.3)	(0.00213)	(0.173)
Δ Commute Length	138.9	-33.07	0.00207	-0.131
	(126.5)	(83.71)	(0.00145)	(0.117)
Δ Pct. Utilizing Public Transit	152.5	98.33	-0.000447	-0.0154
	(191.5)	(126.7)	(0.00219)	(0.178)
Δ Home Price	2.69e-05**	1.76e-05**	2.13e-10*	-2.18e-09
	(1.09e-05)	(7.24e-06)	(1.25e-10)	(1.02e-08)
Initial value	0.0112***	0.0113***	-0.00300***	-0.00822***
	(0.00138)	(0.00115)	(0.00109)	(0.00150)
Distance to CBD	-2.055	1.125	0.000134***	0.0103***
	(2.425)	(1.383)	(3.10e-05)	(0.00229)
Distance to Freeway	-1.303	-3.436	-0.000404***	0.0216***
	(6.271)	(3.557)	(7.93e-05)	(0.00576)
Pct. Commuting to CBD	144.0	338.8***	-0.00112	0.280*
	(166.5)	(94.12)	(0.00201)	(0.143)
Pct. Residential	-91.09***	-68.80***	-3.87e-05	-0.0548***
	(20.62)	(11.63)	(0.000263)	(0.0192)
Δ Station Operational X Retro X Hlf-Mile	-147.0*	106.3*	-0.00111	0.156*
	(87.89)	(58.10)	(0.00101)	(0.0815)
Δ Station Operational X New X Hlf-Mile	-23.26	10.38	0.000477	0.253***
	(96.32)	(63.61)	(0.00111)	(0.0892)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 29 - Effect of Light Rail on Population Characteristics, Anticipatory Model with Dummy for Toll

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Pct. Black	Δ Age
Independent Variable				
Δ Lag Pct. Black	5,644***	542.5		-0.615
	(1,521)	(976.3)		(1.418)
Δ Age	-158.7***	-87.58***	0.000321	
	(18.93)	(12.34)	(0.000220)	
Δ Education	169.6	105.0	-0.000421	0.194
	(146.8)	(97.31)	(0.00169)	(0.137)
Δ Lag Income	0.00240***	0.00125**	-4.60e-10	2.07e-06**
	(0.000868)	(0.000576)	(9.99e-09)	(8.08e-07)
Δ Lag Unemployment	140.8	-38.72	-0.00512	0.459*
	(292.3)	(194.3)	(0.00336)	(0.272)
Δ Lag Poverty	-429.2**	-350.4***	-0.000642	-0.488***
	(185.5)	(123.3)	(0.00213)	(0.173)
Δ Commute Length	64.65	-23.42	0.00210	-0.0889
	(127.1)	(84.50)	(0.00146)	(0.118)
Δ Pct. Utilizing Public Transit	102.9	102.0	-0.000510	0.00450
	(190.5)	(126.6)	(0.00219)	(0.177)
Δ Home Price	2.73e-05**	1.76e-05**	2.15e-10*	-3.06e-09
	(1.09e-05)	(7.24e-06)	(1.25e-10)	(1.02e-08)
Initial value	0.0102***	0.0110***	-0.00296***	-0.00786***
	(0.00146)	(0.00124)	(0.00110)	(0.00152)
Distance to CBD	-2.138	1.158	0.000133***	0.0106***
	(2.431)	(1.385)	(3.12e-05)	(0.00231)
Distance to Freeway	-1.013	-3.393	-0.000403***	0.0212***
	(6.284)	(3.560)	(7.99e-05)	(0.00580)
Pct. Commuting to CBD	119.5	334.2***	-0.00125	0.307**
	(167.7)	(94.81)	(0.00203)	(0.145)
Pct. Residential	-84.54***	-68.02***	-2.35e-05	-0.0580***
	(20.68)	(11.65)	(0.000265)	(0.0193)
Toll Operational	32.07***	-0.937	-2.81e-05	-0.0156**
	(6.974)	(4.652)	(7.99e-05)	(0.00649)
Δ Anticipatory X Retro X Qtr-Mile	1,708**	1,071**	0.00174	-1.150*
	(731.5)	(465.9)	(0.00862)	(0.683)
Δ Anticipatory X New X Qtr-Mile	2,653**	727.5	-0.00505	1.326
	(1,116)	(702.0)	(0.0128)	(0.996)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 30 - Effect of Light Rail on Log of Population and Housing, Anticipatory Model

	Dependent Variable	
	Δ log(Population)	Δ log(Housing)
Independent Variable		
Δ Lag Black	0.433***	0.0636
	(0.118)	(0.124)
Δ Age	-0.0232***	-0.0124***
	(0.00144)	(0.00153)
Δ Education	0.0235**	0.0164
	(0.0108)	(0.0116)
Δ Lag Income	1.47e-07**	1.70e-07**
	(6.41e-08)	(6.85e-08)
Δ Lag Unemployment	-0.00524	-0.0410*
	(0.0215)	(0.0230)
Δ Lag Poverty	-0.0330**	-0.0151
	(0.0137)	(0.0146)
Δ Commute Length	0.00629	-0.0116
	(0.00928)	(0.00992)
Δ Pct. Utilizing Public Transit	0.00858	0.0138
	(0.0141)	(0.0150)
Δ Home Price	1.29e-09	1.71e-09**
	(8.04e-10)	(8.60e-10)
Initial value	-1.55e-07	-6.44e-08
	(1.46e-07)	(2.11e-07)
Distance to CBD	0.000224	0.000518**
	(0.000246)	(0.000241)
Distance to Freeway	0.000830	0.000709
	(0.000638)	(0.000622)
Percent Commuting to CBD	0.0148	0.0447***
	(0.0170)	(0.0165)
Pct. Residential	-0.0128***	-0.0128***
	(0.00210)	(0.00204)
Δ Anticipatory X Retro X Qtr-Mile	0.0984*	0.161***
	(0.0572)	(0.0603)
Δ Anticipatory X New X Qtr-Mile	0.0925	0.0504
	(0.0905)	(0.0952)
Observations	3,204	3,204
Number of tracts	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 31 - Effect of Light Rail on Population Characteristics, Contemporaneous Model with Dummy for Toll

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Pct. Black	Δ Age
Independent Variable				
Δ Lag Pct. Black	5,585***	533.0		-0.627
	(1,524)	(976.6)		(1.416)
Δ Age	-157.8***	-88.09***	0.000322	
	(18.96)	(12.33)	(0.000220)	
Δ Education	174.4	106.7	-0.000402	0.189
	(147.0)	(97.44)	(0.00169)	(0.137)
Δ Lag Income	0.00234***	0.00123**	-4.84e-10	2.1e-06***
	(0.000869)	(0.000577)	(9.99e-09)	(8.08e-07)
Δ Lag Unemployment	161.0	-30.92	-0.00514	0.462*
	(292.5)	(194.4)	(0.00336)	(0.272)
Δ Lag poverty	-423.7**	-349.4***	-0.000666	-0.483***
	(185.6)	(123.4)	(0.00213)	(0.173)
Δ Commute Length	54.39	-29.96	0.00211	-0.0919
	(127.2)	(84.59)	(0.00146)	(0.118)
Δ Pct. Utilizing Public Transit	127.0	109.0	-0.000560	0.0154
	(190.5)	(126.6)	(0.00219)	(0.177)
Δ Home Price	2.74e-05**	1.76e-05**	2.13e-10*	-2.38e-09
	(1.09e-05)	(7.25e-06)	(1.25e-10)	(1.02e-08)
Initial Value	0.0112***	0.0114***	-0.00295***	-0.0082***
	(0.00139)	(0.00115)	(0.00110)	(0.00150)
Distance to CBD	-2.263	1.177	0.000133***	0.0104***
	(2.448)	(1.382)	(3.12e-05)	(0.00229)
Distance to Freeway	-1.057	-3.517	-0.00040***	0.0214***
	(6.334)	(3.557)	(7.99e-05)	(0.00576)
Pct. Commuting to CBD	126.1	344.9***	-0.00127	0.295**
	(168.0)	(94.02)	(0.00202)	(0.143)
Pct. Residential	-88.64***	-69.56***	-2.49e-05	-0.0567***
	(20.82)	(11.62)	(0.000265)	(0.0192)
Toll-Operational	31.01***	-1.399	-2.98e-05	-0.0144**
	(6.975)	(4.654)	(7.99e-05)	(0.00649)
Δ Station Operational X Retro X Qtr-Mile	133.3	123.2	0.000223	0.0459
	(146.0)	(96.76)	(0.00168)	(0.136)
Δ Station Operational X New X Qtr-Mile	-80.63	32.97	-0.00218	0.905***
	(373.4)	(247.6)	(0.00430)	(0.347)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 32 - Effect of Light Rail on Log of Population and Housing, Contemporaneous Model

	Dependent Variable	
	Δ log(Population)	Δ log(Housing)
Independent Variable		
Δ Lag Black	0.431***	0.0629
	(0.118)	(0.124)
Δ Age	-0.0232***	-0.0125***
	(0.00144)	(0.00153)
Δ Education	0.0236**	0.0163
	(0.0108)	(0.0116)
Δ Lag Income	1.44e-07**	1.68e-07**
	(6.41e-08)	(6.86e-08)
Δ Lag Unemployment	-0.00453	-0.0402*
	(0.0215)	(0.0230)
Δ Lag Poverty	-0.0329**	-0.0151
	(0.0137)	(0.0146)
Δ Commute Length	0.00571	-0.0125
	(0.00928)	(0.00994)
Δ Pct. Utilizing Public Transit	0.00944	0.0144
	(0.0140)	(0.0150)
Δ Home Price	1.28e-09	1.68e-09*
	(8.04e-10)	(8.60e-10)
Initial value	-1.25e-07	-4.40e-08
	(1.41e-07)	(2.02e-07)
Distance to CBD	0.000223	0.000528**
	(0.000247)	(0.000241)
Distance to Freeway	0.000819	0.000683
	(0.000640)	(0.000621)
Percent Commuting to CBD	0.0159	0.0470***
	(0.0170)	(0.0164)
Pct. Residential	-0.0130***	-0.0130***
	(0.00211)	(0.00204)
Δ Station Operational X Retro X Qtr-Mile	0.00640	0.0143
	(0.0108)	(0.0115)
Δ Station Operational X New X Qtr-Mile	-0.00602	0.0124
	(0.0276)	(0.0295)
Observations	3,204	3,204
Number of tracts	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 33 - Effect of Light Rail on Prevalence of Young and Educated Residents, Anticipatory Model

	Dependent Variable	
	Δ Pct. Young	Δ Educated*
Independent Variable		
Δ Lag Black	0.0841***	-0.560***
	(0.0281)	(0.156)
Δ Age		-0.000711
		(0.00206)
Δ Education	-0.00841***	
	(0.00312)	
Δ Lag Income	-4.57e-08**	8.42e-08
	(1.85e-08)	(1.06e-07)
Δ Lag Unemployment	-0.0169***	0.0587*
	(0.00626)	(0.0357)
Δ Lag Poverty	0.0117***	-0.0167
	(0.00398)	(0.0227)
Δ Commute Length	-0.000350	0.0327**
	(0.00270)	(0.0154)
Δ Pct. Utilizing Public Transit	-0.00143	-0.0532**
	(0.00408)	(0.0233)
Δ Home Price	1.87e-10	8.40e-10
	(2.34e-10)	(1.33e-09)
Initial value	-0.00663***	-0.00807***
	(0.00109)	(0.00259)
Distance to CBD	-0.000118***	-0.000308*
	(3.14e-05)	(0.000173)
Distance to Freeway	-0.000127	0.00108**
	(8.10e-05)	(0.000442)
Percent Commuting to CBD	-0.00376*	0.0139
	(0.00200)	(0.0105)
Pct. Residential	0.000745***	-0.000299
	(0.000263)	(0.00139)
Δ Anticipatory X Retro X Qtr-Mile	0.0442***	-0.0241
	(0.0132)	(0.0720)
Δ Anticipatory X New X Qtr-Mile	-0.0446***	-0.0606
	(0.0173)	(0.0922)
Observations	3,204	3,204
Number of tracts	356	356

*Education is imputed for 2004 through 2008

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 34 - Effect of Light Rail on Prevalence of Young and Educated Residents, Contemporaneous Model

	Dependent Variable	
	Δ Pct. Young	Δ Educated*
Independent Variable		
Δ Lag Black	0.0870***	-0.555***
	(0.0280)	(0.156)
Δ Age		-0.000879
		(0.00206)
Δ Education	-0.00830***	
	(0.00312)	
Δ Lag Income	-4.63e-08**	8.63e-08
	(1.85e-08)	(1.06e-07)
Δ Lag Unemployment	-0.0171***	0.0583
	(0.00626)	(0.0357)
Δ Lag Poverty	0.0115***	-0.0171
	(0.00398)	(0.0227)
Δ Commute Length	-0.000363	0.0335**
	(0.00270)	(0.0154)
Δ Pct. Utilizing Public Transit	-0.00190	-0.0536**
	(0.00408)	(0.0232)
Δ Home Price	1.53e-10	8.05e-10
	(2.34e-10)	(1.33e-09)
Initial value	-0.00747***	-0.00776***
	(0.00106)	(0.00259)
Distance to CBD	-0.000111***	-0.000292*
	(3.10e-05)	(0.000173)
Distance to Freeway	-0.000141*	0.00108**
	(8.01e-05)	(0.000441)
Percent Commuting to CBD	-0.00330*	0.0135
	(0.00196)	(0.0104)
Pct. Residential	0.000686***	-0.000375
	(0.000260)	(0.00138)
Δ Station Operational X Retro X Qtr-Mile	-0.00170	-0.0192
	(0.00309)	(0.0175)
Δ Station Operational X New X Qtr-Mile	-0.0358***	0.0526
	(0.00789)	(0.0450)
Observations	3,204	3,204
Number of tracts	356	356

*Education is imputed for 2004 through 2008

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 35 - Effect of Distance to Toll on Population Characteristics, Anticipatory Model

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Lag Black	Δ Age
Independent Variable				
Δ Lag Black	3,457**	455.4		-4.658***
	(1,563)	(993.2)		(1.453)
Δ Lag Income	0.00193**	0.00111*	3.62e-09	1.67e-06**
	(0.000865)	(0.000575)	(9.17e-09)	(7.83e-07)
Δ Lag Unemployment	247.8	-23.34	0.00187	0.422
	(291.5)	(194.1)	(0.00308)	(0.264)
Δ Lag Poverty	-460.7**	-360.5***	0.00303	-0.502***
	(185.1)	(123.2)	(0.00196)	(0.167)
Δ Age	-186.5***	-87.15***	-0.0006***	
	(19.23)	(12.46)	(0.000212)	
Δ Education	160.7	99.22	-0.00312**	0.0383
	(146.3)	(97.12)	(0.00155)	(0.133)
Δ Commute Length	89.11	-20.29	-0.000604	-0.260**
	(126.2)	(84.10)	(0.00134)	(0.114)
Δ Pct. Utilizing Public Transit	96.87	88.33	0.00333*	-0.0157
	(189.6)	(126.3)	(0.00201)	(0.172)
Initial Value	0.0147***	0.0138***	0.00171	0.00571***
	(0.00124)	(0.000982)	(0.00143)	(0.00173)
Pct. Residential	-96.04***	-64.78***	-6.54e-05	-0.0413**
	(19.24)	(10.59)	(0.000308)	(0.0201)
Distance to CBD	2.757	2.867	-0.000129**	0.0136***
	(3.666)	(2.033)	(5.93e-05)	(0.00381)
Percent Commuting to CBD	60.41	305.3***	-0.00858***	0.0562
	(171.9)	(96.95)	(0.00264)	(0.174)
Eastside	5.271	15.75	0.000575*	-0.0340
	(20.61)	(11.45)	(0.000333)	(0.0220)
Anticipatory Weight	110.3***	13.80	0.00268***	0.226***
	(18.27)	(12.18)	(0.000187)	(0.0160)
Distance to I-90	-2.130	-1.319	7.51e-05*	0.00332
	(2.638)	(1.461)	(4.40e-05)	(0.00275)
Distance to 520	2.996	0.679	0.000403***	0.00768**
	(3.052)	(1.745)	(4.98e-05)	(0.00313)
Anticipatory Weight X Distance to 520	-9.907***	-1.246	-0.00037***	-0.0217***
	(2.089)	(1.393)	(2.11e-05)	(0.00185)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 36 - Effect of Distance to Toll on Population Characteristics, Contemporaneous Model				
	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Lag Black	Δ Age
Independent Variable				
Δ Lag Black	3,736**	459.0		-5.103***
	(1,577)	(1,001)		(1.486)
Δ Lag Income	0.00209**	0.00112*	2.25e-09	1.83e-06**
	(0.000865)	(0.000575)	(9.07e-09)	(7.96e-07)
Δ Lag Unemployment	198.6	-16.81	0.000519	0.494*
	(291.4)	(194.0)	(0.00305)	(0.268)
Δ Lag Poverty	-434.0**	-352.9***	0.00328*	-0.412**
	(185.0)	(123.1)	(0.00193)	(0.170)
Δ Age	-166.4***	-85.18***	-0.00062***	
	(18.96)	(12.29)	(0.000206)	
Δ Education	172.1	107.3	-0.00283*	0.142
	(146.3)	(97.07)	(0.00154)	(0.135)
Δ Commute Length	89.03	-6.795	1.51e-05	-0.0877
	(126.6)	(84.28)	(0.00132)	(0.116)
Δ Pct. Utilizing Public Transit	85.45	88.12	0.00281	-0.0287
	(189.8)	(126.3)	(0.00198)	(0.175)
Initial Value	0.0148***	0.0138***	0.00172	0.00568***
	(0.00125)	(0.000982)	(0.00143)	(0.00173)
Pct. Residential	-95.18***	-64.71***	-6.84e-05	-0.0417**
	(19.24)	(10.59)	(0.000308)	(0.0201)
Distance to CBD	2.532	2.852	-0.000128**	0.0137***
	(3.668)	(2.033)	(5.93e-05)	(0.00381)
Percent Commuting to CBD	54.38	304.3***	-0.00859***	0.0514
	(172.0)	(96.96)	(0.00264)	(0.174)
Eastside	5.618	15.76	0.000574*	-0.0339
	(20.62)	(11.45)	(0.000333)	(0.0220)
Toll Operational	86.86***	4.544	0.00259***	0.114***
	(16.22)	(10.81)	(0.000163)	(0.0148)
Distance to I-90	-2.228	-1.332	7.52e-05*	0.00330
	(2.639)	(1.461)	(4.40e-05)	(0.00275)
Distance to 520	0.489	0.321	0.000339***	0.00237
	(2.928)	(1.648)	(4.91e-05)	(0.00304)
Toll Operational X Distance to 520	-7.224***	-0.795	-0.00036***	-0.0166***
	(1.886)	(1.256)	(1.87e-05)	(0.00171)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 37 - Effect of Toll on Population Characteristics, Anticipatory Model with Dummy for Light Rail - Comparison Group I Proximity Measurement

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Lag Black	Δ Age
Independent Variable				
Δ Lag Black	4,824***	470.1		-1.268
	(1,517)	(964.3)		(1.394)
Δ Lag Income	0.00211**	0.00112*	8.05e-09	1.77e-06**
	(0.000867)	(0.000574)	(9.55e-09)	(7.72e-07)
Δ Lag Unemployment	172.6	-22.22	-0.000678	0.297
	(292.3)	(193.9)	(0.00321)	(0.260)
Δ Lag Poverty	-451.4**	-363.8***	0.00421**	-0.449***
	(186.0)	(123.3)	(0.00204)	(0.165)
Δ Age	-174.6***	-89.76***	-0.000123	
	(19.47)	(12.56)	(0.000222)	
Δ Education	178.6	96.11	-0.00340**	-0.0120
	(147.3)	(97.47)	(0.00162)	(0.131)
Δ Commute Length	95.87	-16.74	-0.000164	-0.190*
	(126.8)	(84.09)	(0.00139)	(0.113)
Δ Pct. Utilizing Public Transit	94.33	90.85	0.00336	-0.0570
	(190.5)	(126.3)	(0.00209)	(0.169)
Initial Value	0.0144***	0.0135***	0.00534***	0.00614***
	(0.00125)	(0.000995)	(0.00133)	(0.00175)
Pct. Residential	-96.39***	-66.14***	-7.12e-05	-0.0401**
	(19.10)	(10.56)	(0.000300)	(0.0201)
Distance to CBD	-0.396	1.363	4.56e-05	0.0153***
	(2.434)	(1.360)	(3.85e-05)	(0.00255)
Percent Commuting to CBD	76.60	298.5***	-0.00580**	0.101
	(170.5)	(96.43)	(0.00253)	(0.172)
Eastside	18.68	18.84**	-5.98e-06	-0.0275
	(17.08)	(9.534)	(0.000279)	(0.0184)
LR Operational	5.877	23.46**	0.000158	0.183***
	(17.07)	(11.36)	(0.000187)	(0.0148)
Anticipatory Weight	22.42	-20.76	-0.000573***	-0.154***
	(19.93)	(13.27)	(0.000218)	(0.0175)
Proximity 520	0.346	-8.215	-0.00273***	-0.0909**
	(36.69)	(21.74)	(0.000532)	(0.0371)
Proximity I-90	-25.83	-15.13	-0.00309***	0.0353
	(28.07)	(15.82)	(0.000452)	(0.0293)
Anticipatory Weight X Proximity 520	70.28*	-7.796	0.00327***	0.272***
	(39.99)	(26.62)	(0.000433)	(0.0352)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 38 - Effect of Toll on Log of Total Population and Total Housing Units, Anticipatory Model - Comparison Group I Proximity Measurement

	Dependent Variable	
	Δ log(Population)	Δ log(Housing)
Independent Variable		
Δ Lag Black	0.356***	-0.0253
	(0.119)	(0.125)
Δ Lag Income	1.39e-07**	1.67e-07**
	(6.40e-08)	(6.81e-08)
Δ Lag Unemployment	-0.00467	-0.0316
	(0.0215)	(0.0229)
Δ Lag Poverty	-0.0317**	-0.00942
	(0.0137)	(0.0146)
Δ Age	-0.0236***	-0.0112***
	(0.00146)	(0.00154)
Δ Education	0.0223**	0.0193*
	(0.0109)	(0.0116)
Δ Commute Length	0.00716	-0.00322
	(0.00933)	(0.00992)
Δ Pct. Utilizing Public Transit	0.00710	0.0131
	(0.0140)	(0.0149)
Initial Value	1.28e-07	3.05e-07
	(1.37e-07)	(1.91e-07)
Pct. Residential	-0.0137***	-0.0132***
	(0.00210)	(0.00203)
Distance to CBD	0.000248	0.000419
	(0.000266)	(0.000260)
Percent Commuting to CBD	-0.00186	0.0242
	(0.0187)	(0.0185)
Eastside	-0.00179	-0.00212
	(0.00188)	(0.00183)
Anticipatory Weight	-0.000705	-0.00419***
	(0.000586)	(0.000623)
Proximity 520	-0.00450	-0.00676*
	(0.00367)	(0.00364)
Proximity I-90	-0.000129	0.00125
	(0.00307)	(0.00303)
Anticipatory Weight X Proximity 520	0.0102***	0.00582*
	(0.00293)	(0.00312)
Observations	3,204	3,204
Number of tracts	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 39 - Effect of Toll on Log of Total Population and Total Housing, Contemporaneous Model - Comparison Group I Proximity Measurement

	Dependent Variable	
	Δ log(Population)	Δ log(Housing)
Independent Variable		
Δ Lag Black	0.393***	-0.0206
	(0.119)	(0.125)
Δ Lag Income	1.43e-07**	1.54e-07**
	(6.40e-08)	(6.80e-08)
Δ Lag Unemployment	-0.00840	-0.0314
	(0.0215)	(0.0229)
Δ Lag Poverty	-0.0329**	-0.0113
	(0.0137)	(0.0146)
Δ Age	-0.0233***	-0.0129***
	(0.00145)	(0.00153)
Δ Education	0.0215**	0.0198*
	(0.0109)	(0.0116)
Δ Commute Length	0.00366	-0.00172
	(0.00935)	(0.00994)
Δ Pct. Utilizing Public Transit	0.00748	0.0139
	(0.0140)	(0.0149)
Initial Value	1.29e-07	2.93e-07
	(1.37e-07)	(1.91e-07)
Pct. Residential	-0.0137***	-0.0133***
	(0.00210)	(0.00203)
Distance to CBD	0.000242	0.000444*
	(0.000266)	(0.000260)
Percent Commuting to CBD	-0.00176	0.0250
	(0.0187)	(0.0185)
Eastside	-0.00178	-0.00213
	(0.00188)	(0.00183)
Toll Operational	0.000989*	-0.00387***
	(0.000528)	(0.000562)
Proximity 520	-0.00131	-0.00504
	(0.00348)	(0.00341)
Proximity I-90	-5.35e-05	0.00131
	(0.00307)	(0.00302)
Toll Operational X Proximity 520	0.00580**	0.00376
	(0.00265)	(0.00281)
Observations	3,204	3,204
Number of tracts	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 40 - Effect of Toll on Population Characteristics, Anticipatory Model with Dummy for Light Rail – Comparison Group II Proximity Measurement

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Lag Black	Δ Age
Independent Variable				
Distance to CBD	3.482	3.493**	3.67e-05	0.0127***
	(2.730)	(1.519)	(4.51e-05)	(0.00283)
Percent Commuting to CBD	90.47	328.9***	-0.00615**	0.175
	(167.8)	(94.52)	(0.00263)	(0.169)
Eastside	7.425	15.77	-0.000129	-0.00445
	(17.96)	(9.890)	(0.000299)	(0.0193)
Δ Lag Black	3,181**	303.6		-5.657***
	(1,538)	(975.4)		(1.384)
Δ Lag Income	0.00202**	0.00112*	5.72e-09	1.60e-06**
	(0.000863)	(0.000574)	(9.26e-09)	(7.51e-07)
Δ Lag Unemployment	205.8	-21.61	0.000118	0.357
	(290.6)	(193.8)	(0.00311)	(0.253)
Δ Lag Poverty	-450.7**	-364.7***	0.00353*	-0.465***
	(184.7)	(123.1)	(0.00198)	(0.161)
Δ Age	-201.3***	-98.19***	-0.000813***	
	(19.88)	(12.86)	(0.000222)	
Δ Education	157.4	96.10	-0.00326**	-0.0198
	(146.0)	(97.07)	(0.00157)	(0.127)
Δ Commute Length	95.45	-14.65	-0.000289	-0.198*
	(126.0)	(84.06)	(0.00135)	(0.110)
Δ Pct. Utilizing Public Transit	57.63	73.89	0.00252	-0.0986
	(189.4)	(126.3)	(0.00203)	(0.165)
Initial Value	0.0139***	0.0134***	0.00311**	0.00508***
	(0.00128)	(0.000999)	(0.00138)	(0.00174)
Pct. Residential	-90.45***	-61.79***	2.25e-05	-0.0365*
	(19.04)	(10.46)	(0.000314)	(0.0199)
LR Operational	11.16	25.05**	0.000286	0.183***
	(17.00)	(11.38)	(0.000181)	(0.0144)
Anticipatory Weight	-15.53	-29.57**	-0.00153***	-0.221***
	(20.90)	(13.98)	(0.000221)	(0.0177)
Proximity 520	-54.90***	-19.69*	-0.00195***	-0.189***
	(20.59)	(11.91)	(0.000319)	(0.0202)
Proximity I-90	53.37***	28.46***	-0.000594**	0.0325*
	(17.72)	(9.804)	(0.000295)	(0.0185)
Anticipatory Weight X Proximity 520	107.7***	20.99*	0.00299***	0.229***
	(18.07)	(12.05)	(0.000186)	(0.0152)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 41 - Effect of Toll on Log of Total Population and Total Housing Units, Anticipatory Model – Comparison Group II Proximity Measurement

	Dependent Variable	
	Δ log(Population)	Δ log(Housing)
Independent Variable		
Distance to CBD	0.000845***	0.000883***
	(0.000297)	(0.000291)
Percent Commuting to CBD	0.00419	0.0334*
	(0.0182)	(0.0181)
Eastside	-0.00365*	-0.00293
	(0.00196)	(0.00190)
Δ Lag Black	0.188	-0.112
	(0.121)	(0.128)
Δ Lag Income	1.32e-07**	1.64e-07**
	(6.35e-08)	(6.80e-08)
Δ Lag Unemployment	-0.00152	-0.0300
	(0.0214)	(0.0229)
Δ Lag Poverty	-0.0329**	-0.0107
	(0.0136)	(0.0145)
Δ Age	-0.0258***	-0.0125***
	(0.00149)	(0.00158)
Δ Education	0.0224**	0.0204*
	(0.0108)	(0.0115)
Δ Commute Length	0.00687	-0.00330
	(0.00926)	(0.00991)
Δ Pct. Utilizing Public Transit	0.00452	0.0114
	(0.0139)	(0.0149)
Initial Value	1.04e-08	2.04e-07
	(1.39e-07)	(1.92e-07)
Pct. Residential	-0.0129***	-0.0126***
	(0.00207)	(0.00201)
Anticipatory Weight	-0.00352***	-0.00572***
	(0.000716)	(0.000767)
Proximity 520	-0.00298	-0.00268
	(0.00210)	(0.00207)
Proximity I-90	0.00629***	0.00503***
	(0.00193)	(0.00188)
Anticipatory Weight X Proximity 520	0.00992***	0.00543***
	(0.00133)	(0.00142)
Observations	3,204	3,204
Number of tracts	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 42 - Effect of Toll on Log of Total Population and Total Housing Units, Contemporaneous Model – Comparison Group II Proximity Measurement

	Dependent Variable	
	Δ log(Population)	Δ log(Housing)
Independent Variable		
Distance to CBD	0.000828***	0.000894***
	(0.000297)	(0.000292)
Percent Commuting to CBD	0.00611	0.0350*
	(0.0183)	(0.0181)
Eastside	-0.00359*	-0.00289
	(0.00196)	(0.00191)
Δ Lag Black	0.421***	0.00349
	(0.118)	(0.125)
Δ Lag Income	1.43e-07**	1.55e-07**
	(6.40e-08)	(6.81e-08)
Δ Lag Unemployment	-0.00822	-0.0312
	(0.0215)	(0.0229)
Δ Lag Poverty	-0.0331**	-0.0124
	(0.0137)	(0.0146)
Δ Age	-0.0233***	-0.0130***
	(0.00145)	(0.00153)
Δ Education	0.0224**	0.0215*
	(0.0109)	(0.0115)
Δ Commute Length	0.00393	-0.00156
	(0.00935)	(0.00995)
Δ Pct. Utilizing Public Transit	0.00719	0.0137
	(0.0140)	(0.0149)
Initial Value	5.02e-09	1.94e-07
	(1.39e-07)	(1.92e-07)
Pct. Residential	-0.0128***	-0.0126***
	(0.00208)	(0.00201)
Toll Operational	0.00103*	-0.00378***
	(0.000527)	(0.000561)
Proximity 520	0.00215	3.19e-05
	(0.00198)	(0.00193)
Proximity I-90	0.00620***	0.00505***
	(0.00193)	(0.00189)
Toll Operational X Proximity 520	0.00496*	0.00209
	(0.00256)	(0.00271)
Observations	3,204	3,204
Number of tracts	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 43 - Effect of Light Rail and Toll on Population Characteristics, Contemporaneous Model - Comparison Group I Proximity Measurement

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Lag Black	Δ Age
Independent Variable				
Distance to CBD	-1.822	0.600	7.65e-05**	0.0145***
	(2.576)	(1.458)	(3.21e-05)	(0.00246)
Pct. Commuting to CBD	174.4	344.8***	-0.00398**	0.205
	(169.5)	(95.06)	(0.00196)	(0.150)
Δ Lag Black	5,421***	452.5		-1.464
	(1,553)	(998.7)		(1.442)
Δ Lag income	0.00234***	0.00125**	-1.32e-10	2.03e-06**
	(0.000869)	(0.000577)	(9.89e-09)	(8.01e-07)
Δ Lag unemployment	161.2	-25.01	-0.00540	0.428
	(292.7)	(194.5)	(0.00333)	(0.270)
Δ Lag poverty	-431.0**	-356.9***	-0.000308	-0.344**
	(186.2)	(123.7)	(0.00212)	(0.172)
Δ Age	-158.3***	-86.09***	0.000165	
	(19.12)	(12.44)	(0.000220)	
Δ Education	185.4	111.1	-0.000952	0.0988
	(147.5)	(97.80)	(0.00168)	(0.136)
Δ Commute Length	54.44	-35.07	0.00219	-0.0663
	(127.4)	(84.66)	(0.00145)	(0.117)
Δ Pct. Utilizing Public Transit	125.5	117.6	-0.000976	-0.0514
	(190.8)	(126.8)	(0.00217)	(0.176)
Initial Value	0.0108***	0.0111***	0.00469***	0.00494***
	(0.00140)	(0.00117)	(0.00111)	(0.00169)
Pct. Residential	-87.97***	-70.56***	-0.000179	-0.0383*
	(20.75)	(11.64)	(0.000257)	(0.0198)
Toll Operational	30.91***	-0.116	-0.000147*	-0.0266***
	(7.224)	(4.816)	(8.17e-05)	(0.00664)
Proximity 520	40.20	-5.982	-0.00166***	-0.0370
	(35.33)	(20.44)	(0.000436)	(0.0339)
Proximity 90	-34.14	-20.01	-0.00250***	0.0300
	(30.23)	(17.28)	(0.000379)	(0.0287)
Toll Operational X Proximity 520	1.196	-25.83	0.00242***	0.248***
	(36.76)	(24.49)	(0.000414)	(0.0336)
Δ Station Operational X Retro X Qtr-Mile	132.7	121.6	-1.99e-05	0.0169
	(146.1)	(96.80)	(0.00166)	(0.135)
Δ Station Operational X New X Qtr-Mile	-57.42	43.07	-0.00269	0.901***
	(373.9)	(247.9)	(0.00426)	(0.345)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 44 - Effect of Light Rail and Toll on Population Characteristics, Contemporaneous Model - Comparison Group II Proximity Measurement

	Dependent Variable			
	Δ Population Density	Δ Housing Density	Δ Lag Black	Δ Age
Independent Variable				
Distance to CBD	3.137	3.350**	3.56e-05	0.0128***
	(2.738)	(1.521)	(4.50e-05)	(0.00282)
Pct. Commuting to CBD	72.97	318.8***	-0.00621**	0.166
	(168.4)	(94.75)	(0.00263)	(0.169)
Eastside	7.260	15.62	-0.000127	-0.00424
	(18.01)	(9.906)	(0.000299)	(0.0192)
Δ Lag Black	3,180**	334.3		-5.634***
	(1,549)	(981.9)		(1.452)
Δ Lag income	0.00212**	0.00116**	3.51e-09	1.94e-06**
	(0.000863)	(0.000575)	(9.18e-09)	(7.90e-07)
Δ Lag unemployment	152.8	-25.03	-0.00128	0.396
	(290.6)	(193.9)	(0.00309)	(0.266)
Δ Lag poverty	-406.2**	-350.5***	0.00427**	-0.360**
	(184.6)	(123.2)	(0.00196)	(0.169)
Δ Age	-176.6***	-89.72***	-0.000697***	
	(19.05)	(12.36)	(0.000210)	
Δ Education	164.6	111.6	-0.00325**	0.105
	(146.0)	(97.14)	(0.00156)	(0.134)
Δ Commute Length	108.1	-5.857	0.000709	-0.0567
	(126.4)	(84.35)	(0.00134)	(0.116)
Δ Pct. Utilizing Public Transit	15.77	69.45	0.00118	-0.129
	(189.8)	(126.6)	(0.00202)	(0.174)
Initial Value	0.0140***	0.0135***	0.00313**	0.00508***
	(0.00128)	(0.00100)	(0.00138)	(0.00173)
Pct. Residential	-89.11***	-61.11***	2.56e-05	-0.0373*
	(19.11)	(10.48)	(0.000314)	(0.0198)
Toll Operational	-1.155	-6.894	-0.00124***	-0.0721***
	(8.983)	(6.009)	(9.26e-05)	(0.00812)
Proximity 520	-30.01	-13.85	-0.00141***	-0.128***
	(19.19)	(10.80)	(0.000308)	(0.0192)
Proximity 90	52.47***	27.99***	-0.000595**	0.0315*
	(17.78)	(9.826)	(0.000295)	(0.0185)
Toll Operational X Proximity 520	91.01***	15.42	0.00289***	0.166***
	(16.23)	(10.84)	(0.000165)	(0.0146)
Δ Station Operational X Retro X Qtr-Mile	147.0	118.2	0.000407	0.0662
	(144.9)	(96.37)	(0.00155)	(0.133)
Δ Station Operational X New X Qtr-Mile	-55.76	46.48	-0.00150	0.922***
	(370.9)	(246.7)	(0.00396)	(0.340)
Observations	3,204	3,204	3,204	3,204
Number of tracts	356	356	356	356

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 45 - Effect of Light Rail on Employment Characteristics, Anticipatory Model – Stratified by Presence of Tract Within ½ Mile of Station

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0521	2.47e-08
	(0.0454)	(4.27e-07)
Δ Lag Pct. Black	-4,319	-0.147
	(55,790)	(0.525)
Δ Age	775.7	0.00831
	(776.1)	(0.00730)
Δ Education	-6,325	-0.0605
	(6,813)	(0.0634)
Δ Lag Income	0.0254	-2.73e-07
	(0.0636)	(5.96e-07)
Δ Lag Unemployment	-22,978*	0.00346
	(13,813)	(0.130)
Δ Lag Poverty	-735.8	0.0774
	(7,699)	(0.0721)
Δ Commute Length	-5,538	0.0888
	(6,918)	(0.0649)
Δ Pct. Utilizing Public Transit	-11,898	0.0437
	(8,824)	(0.0828)
Δ Home Price	-0.000482	3.73e-10
	(0.000501)	(4.71e-09)
Initial value	0.00960	-0.0178
	(0.00866)	(0.0142)
Distance to CBD	127.0	0.000273
	(109.2)	(0.000996)
Distance to Freeway	87.37	0.000183
	(464.2)	(0.00432)
Pct. Commuting to CBD	7,019	0.0305
	(5,364)	(0.0442)
Pct. Residential	555.8	0.000448
	(764.7)	(0.00711)
Δ Anticipatory X Retro X Qtr-Mile	-24,422	-0.00170
	(16,340)	(0.142)
Δ Anticipatory X New X Qtr-Mile	-138.7	-0.414***
	(12,097)	(0.116)
Observations	486	486
Number of tracts	54	54

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 46 - Effect of Light Rail on Employment Characteristics, Contemporaneous Model – Stratified by Presence of Tract within ½ Mile of Station

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0997*	2.08e-07
	(0.0603)	(5.08e-07)
Δ Lag Pct. Black	-28,199	-0.0829
	(81,680)	(0.691)
Δ Age	1,458	0.0244*
	(1,516)	(0.0129)
Δ Education	-15,260	-0.00159
	(12,542)	(0.106)
Δ Lag Income	0.0551	-2.92e-07
	(0.103)	(8.67e-07)
Δ Lag Unemployment	-33,505	-0.0668
	(22,702)	(0.192)
Δ Lag Poverty	-878.7	0.141
	(13,482)	(0.114)
Δ Commute Length	-6,430	0.124
	(10,934)	(0.0922)
Δ Pct. Utilizing Public Transit	-10,155	-0.0494
	(14,208)	(0.119)
Δ Home Price	-0.00150	-3.26e-09
	(0.00116)	(9.71e-09)
Initial value	0.00746	-0.0123
	(0.0120)	(0.0186)
Distance to CBD	214.7	0.000245
	(234.1)	(0.00181)
Distance to Freeway	915.5	-0.000644
	(887.6)	(0.00766)
Pct. Commuting to CBD	9,453	0.0281
	(10,268)	(0.0672)
Pct. Residential	2,564	-0.00880
	(1,868)	(0.0163)
Δ Station Operational X Retro X Qtr-Mile	-15,597***	0.0363
	(4,346)	(0.0362)
Δ Station Operational X New X Qtr-Mile	-1,519	-0.377***
	(4,895)	(0.0417)
Observations	279	279
Number of tracts	31	31

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 47 - Effect of Light Rail on Employment Characteristics, Anticipatory Model and ½ Mile Proximity Measurement

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0377**	3.17e-08
	(0.0177)	(3.16e-07)
Δ Lag Pct. Black	4,150	-0.160
	(11,668)	(0.210)
Δ Age	17.59	-0.00171
	(155.4)	(0.00278)
Δ Education	-608.1	-0.0230
	(1,317)	(0.0236)
Δ Lag Income	0.00132	1.39e-07
	(0.00785)	(1.41e-07)
Δ Lag Unemployment	-5,831**	0.0372
	(2,657)	(0.0476)
Δ Lag Poverty	-1,869	0.0281
	(1,688)	(0.0303)
Δ Commute Length	-311.8	0.0134
	(1,156)	(0.0207)
Δ Pct. Utilizing Public Transit	-2,842	0.0144
	(1,734)	(0.0311)
Δ Home Price	-0.000193*	2.61e-09
	(0.000101)	(1.80e-09)
Initial value	0.0179***	-0.0230***
	(0.00277)	(0.00518)
Distance to CBD	6.085	3.69e-05
	(12.63)	(0.000226)
Distance to Freeway	8.397	-0.000471
	(31.82)	(0.000568)
Pct. Commuting to CBD	379.0	0.00914
	(863.6)	(0.0150)
Pct. Nonresidential	16.64	0.000767
	(111.4)	(0.00192)
Δ Anticipatory X Retro X Hlf-Mile	-12,804***	0.0634
	(3,644)	(0.0558)
Δ Anticipatory X New X Hlf-Mile	4,597**	-0.122***
	(2,101)	(0.0376)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 48 - Effect of Light Rail on Employment Characteristics, Anticipatory Model with Dummy for Toll

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0385**	5.61e-08
	(0.0177)	(3.16e-07)
Δ Lag Pct. Black	4,045	-0.198
	(11,687)	(0.210)
Δ Age	38.42	-0.00153
	(155.4)	(0.00278)
Δ Education	-661.5	-0.0221
	(1,319)	(0.0236)
Δ Lag Income	0.00102	1.28e-07
	(0.00786)	(1.41e-07)
Δ Lag Unemployment	-5,805**	0.0444
	(2,663)	(0.0476)
Δ Lag Poverty	-1,873	0.0305
	(1,690)	(0.0302)
Δ Commute Length	-580.1	0.0158
	(1,166)	(0.0209)
Δ Pct. Utilizing Public Transit	-2,425	0.0170
	(1,736)	(0.0310)
Δ Home Price	-0.000179*	2.41e-09
	(0.000101)	(1.80e-09)
Initial value	0.0172***	-0.0208***
	(0.00273)	(0.00521)
Distance to CBD	3.091	6.88e-05
	(12.60)	(0.000225)
Distance to Freeway	5.792	-0.000501
	(31.82)	(0.000567)
Pct. Commuting to CBD	405.1	0.0139
	(855.7)	(0.0147)
Pct. Nonresidential	52.68	0.00116
	(111.0)	(0.00190)
Toll Operational	71.26	-0.00167
	(65.08)	(0.00116)
Δ Anticipatory X Retro X Qtr-Mile	-24,054***	0.00299
	(6,560)	(0.101)
Δ Anticipatory X New X Qtr-Mile	-718.6	-0.377***
	(4,585)	(0.0826)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 49 - Effect of Light Rail on Log of Total Employment, Anticipatory Model

	Dependent Variable Δ log(employment)
Independent Variable	
Δ Lag Employment Density	-9.85e-07
	(1.89e-06)
Δ Lag Black	0.236
	(1.248)
Δ Age	-0.0355**
	(0.0166)
Δ Education	-0.405***
	(0.141)
Δ Lag Income	-1.09e-06
	(8.40e-07)
Δ Lag Unemployment	0.133
	(0.284)
Δ Lag Poverty	-0.205
	(0.181)
Δ Commute Length	-0.0448
	(0.124)
Δ Pct. Utilizing Public Transit	0.126
	(0.186)
Δ Home Price	-5.85e-09
	(1.08e-08)
Initial value	-7.47e-08
	(2.92e-07)
Distance to CBD	-0.00219
	(0.00135)
Distance to Freeway	0.00728**
	(0.00340)
Percent Commuting to CBD	-0.0462
	(0.0915)
Pct. Nonresidential	0.00919
	(0.0119)
Δ Anticipatory X Retro X Qtr-Mile	-0.143
	(0.699)
Δ Anticipatory X New X Qtr-Mile	-0.522
	(0.490)
Observations	3,159
Number of tracts	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 50 - Effect of Light Rail on Employment Characteristics, Contemporaneous Model and ½ Mile Proximity Measurement

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0625***	2.15e-07
	(0.0177)	(3.14e-07)
Δ Lag Pct. Black	3,946	-0.124
	(11,549)	(0.207)
Δ Age	87.48	-0.000853
	(153.7)	(0.00274)
Δ Education	-566.8	-0.0179
	(1,303)	(0.0232)
Δ Lag Income	0.000716	1.31e-07
	(0.00777)	(1.38e-07)
Δ Lag Unemployment	-5,824**	0.0340
	(2,628)	(0.0469)
Δ Lag poverty	-1,718	0.0229
	(1,670)	(0.0298)
Δ Commute Length	-210.9	0.0121
	(1,141)	(0.0203)
Δ Pct. Utilizing Public Transit	-1,895	0.00652
	(1,715)	(0.0306)
Δ Home Price	-0.000176*	2.62e-09
	(9.96e-05)	(1.77e-09)
Initial Value	0.0170***	-0.0201***
	(0.00238)	(0.00509)
Distance to CBD	2.999	7.93e-06
	(12.43)	(0.000220)
Distance to Freeway	4.636	-0.000411
	(31.45)	(0.000558)
Pct. Commuting to CBD	549.6	0.00520
	(842.2)	(0.0141)
Pct. Nonresidential	69.39	4.57e-05
	(108.5)	(0.00185)
Δ Station Operational X Retro X Hlf-Mile	-6,535***	0.0464***
	(720.2)	(0.0125)
Δ Station Operational X New X Hlf-Mile	-744.6	-0.141***
	(788.3)	(0.0141)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 51 - Effect of Light Rail on Employment Characteristics, Contemporaneous Model with Dummy for Toll

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0709***	1.49e-07
	(0.0176)	(3.11e-07)
Δ Lag Pct. Black	4,048	-0.196
	(11,463)	(0.205)
Δ Age	75.86	-0.000398
	(152.4)	(0.00271)
Δ Education	-572.0	-0.0132
	(1,295)	(0.0230)
Δ Lag Income	0.000638	1.22e-07
	(0.00771)	(1.37e-07)
Δ Lag Unemployment	-6,001**	0.0401
	(2,611)	(0.0464)
Δ Lag poverty	-1,811	0.0244
	(1,657)	(0.0295)
Δ Commute Length	-340.7	0.0143
	(1,143)	(0.0203)
Δ Pct. Utilizing Public Transit	-1,325	0.00206
	(1,703)	(0.0303)
Δ Home Price	-0.000183*	2.25e-09
	(9.87e-05)	(1.76e-09)
Initial Value	0.0184***	-0.0175***
	(0.00236)	(0.00505)
Distance to CBD	3.105	3.73e-05
	(12.32)	(0.000218)
Distance to Freeway	6.047	-0.000482
	(31.20)	(0.000553)
Pct. Commuting to CBD	432.5	0.00978
	(834.5)	(0.0139)
Pct. Nonresidential	52.44	0.000194
	(107.6)	(0.00183)
Toll-Operational	64.95	-0.00210*
	(63.73)	(0.00113)
Δ Station Operational X Retro X Qtr-Mile	-15,712***	0.0389*
	(1,350)	(0.0234)
Δ Station Operational X New X Qtr-Mile	-1,389	-0.357***
	(1,501)	(0.0268)
Observations		
Number of tracts		

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 52– Effect of Toll on Employment Characteristics, Anticipatory Model with Dummy for Light Rail - Comparison Group I Proximity Measurement

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0383**	-2.10e-08
	(0.0178)	(3.17e-07)
Distance to CBD	1.922	6.36e-05
	(13.52)	(0.000239)
Percent Commuting to CBD	349.2	0.0167
	(973.8)	(0.0159)
Eastside	82.56	0.00175
	(96.32)	(0.00168)
Δ Lag Black	-915.2	-0.157
	(11,909)	(0.215)
Δ Lag Income	0.00238	1.52e-07
	(0.00786)	(1.41e-07)
Δ Lag Unemployment	-5,875**	0.0408
	(2,665)	(0.0477)
Δ Lag Poverty	-1,596	0.0311
	(1,697)	(0.0304)
Δ Age	-22.52	-0.000358
	(160.1)	(0.00287)
Δ Education	-911.7	-0.0223
	(1,331)	(0.0238)
Δ Commute Length	-365.6	0.0207
	(1,164)	(0.0208)
Δ Pct. Utilizing Public Transit	-2,802	0.00633
	(1,736)	(0.0311)
Initial Value	0.0131***	-0.0261***
	(0.00247)	(0.00536)
Pct. Nonresidential	65.38	0.000844
	(110.0)	(0.00186)
Light Rail Operational	41.18	-0.00633**
	(158.7)	(0.00284)
Toll Operational	-7.111	0.00439
	(185.5)	(0.00332)
Distance to I-90	-328.4	-0.00325
	(250.5)	(0.00449)
Distance to 520	-152.0	-0.00278
	(153.2)	(0.00274)
Toll Operational X Distance to 520	455.3	0.00284
	(370.7)	(0.00664)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 53 - Effect of Distance to Toll on Employment Characteristics, Anticipatory Model		
	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0381**	2.55e-08
	(0.0177)	(3.16e-07)
Distance to CBD	7.127	0.000156
	(20.00)	(0.000354)
Percent Commuting to CBD	338.9	0.0172
	(986.8)	(0.0162)
Eastside	54.22	0.00121
	(112.9)	(0.00200)
Δ Lag Black	3,008	-0.0917
	(12,165)	(0.219)
Δ Lag Income	0.00225	1.41e-07
	(0.00788)	(1.41e-07)
Δ Lag Unemployment	-5,891**	0.0414
	(2,668)	(0.0478)
Δ Lag Poverty	-1,678	0.0294
	(1,695)	(0.0304)
Δ Age	-1.050	-0.00135
	(158.9)	(0.00285)
Δ Education	-757.3	-0.0223
	(1,324)	(0.0237)
Δ Commute Length	-337.7	0.0228
	(1,164)	(0.0208)
Δ Pct. Utilizing Public Transit	-2,753	0.00571
	(1,735)	(0.0311)
Initial Value	0.0134***	-0.0265***
	(0.00246)	(0.00533)
Pct. Nonresidential	65.90	0.000844
	(112.2)	(0.00190)
Anticipatory Weight	91.11	-0.00271
	(168.9)	(0.00302)
Distance to I-90	-0.364	5.67e-05
	(14.29)	(0.000256)
Distance to 520	-0.989	-0.000123
	(18.65)	(0.000334)
Anticipatory Weight X Distance to 520	-4.202	5.95e-05
	(19.23)	(0.000344)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 54 - Effect of Toll on Log of Total Employment, Anticipatory Model - Comparison Group I Proximity Measurement

	Dependent Variable Δ Log(Total Employment)
Independent Variable	
Δ Lag Employment Density	-1.04e-06
	(1.89e-06)
Distance to CBD	-0.00218
	(0.00144)
Percent Commuting to CBD	-0.0996
	(0.104)
Eastside	-0.00886
	(0.0103)
Δ Lag Black	-0.523
	(1.270)
Δ Lag Income	-1.04e-06
	(8.38e-07)
Δ Lag Unemployment	0.0640
	(0.284)
Δ Lag Poverty	-0.218
	(0.181)
Δ Age	-0.0432**
	(0.0168)
Δ Education	-0.441***
	(0.142)
Δ Commute Length	-0.0917
	(0.124)
Δ Pct. Utilizing Public Transit	0.117
	(0.185)
Initial Value	-7.27e-08
	(2.64e-07)
Pct. Nonresidential	0.00208
	(0.0117)
Anticipatory Weight	0.0148*
	(0.00792)
Proximity 520	-0.0619**
	(0.0267)
Proximity I-90	-0.00769
	(0.0163)
Anticipatory Weight X Proximity 520	0.0735*
	(0.0395)
Observations	3,159
Number of tracts	351

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 55 - Effect of Distance to Toll on Employment Characteristics, Contemporaneous Model

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0388**	3.64e-08
	(0.0177)	(3.17e-07)
Distance to CBD	6.723	0.000167
	(19.99)	(0.000354)
Percent Commuting to CBD	332.4	0.0175
	(986.6)	(0.0162)
Eastside	55.13	0.00118
	(112.8)	(0.00200)
Δ Lag Black	2,894	-0.0755
	(12,229)	(0.220)
Δ Lag Income	0.00254	1.34e-07
	(0.00787)	(1.41e-07)
Δ Lag Unemployment	-5,984**	0.0405
	(2,664)	(0.0477)
Δ Lag Poverty	-1,667	0.0278
	(1,693)	(0.0303)
Δ Age	19.24	-0.00196
	(157.0)	(0.00281)
Δ Education	-795.7	-0.0227
	(1,323)	(0.0237)
Δ Commute Length	-438.1	0.0224
	(1,166)	(0.0209)
Δ Pct. Utilizing Public Transit	-2,773	0.00619
	(1,735)	(0.0311)
Initial Value	0.0134***	-0.0266***
	(0.00246)	(0.00533)
Pct. Nonresidential	68.39	0.000750
	(112.1)	(0.00190)
Toll Operational	138.6	-0.00281
	(150.1)	(0.00269)
Distance to I-90	-0.339	5.60e-05
	(14.29)	(0.000256)
Distance to 520	-0.874	-0.000146
	(16.89)	(0.000303)
Toll Operational X Distance to 520	-6.201	0.000144
	(17.32)	(0.000310)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 56 – Effect of Toll on Employment Characteristics, Anticipatory Model - Comparison Group II Proximity Measurement

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0383**	2.37e-08
	(0.0177)	(3.17e-07)
Distance to CBD	1.436	0.000116
	(15.38)	(0.000269)
Percent Commuting to CBD	364.7	0.0177
	(973.3)	(0.0159)
Eastside	90.83	0.00165
	(103.6)	(0.00183)
Δ Lag Black	1,064	-0.127
	(12,009)	(0.216)
Δ Lag Income	0.00244	1.41e-07
	(0.00787)	(1.41e-07)
Δ Lag Unemployment	-5,906**	0.0420
	(2,665)	(0.0477)
Δ Lag Poverty	-1,683	0.0295
	(1,694)	(0.0304)
Δ Age	-20.76	-0.00163
	(161.2)	(0.00289)
Δ Education	-798.1	-0.0229
	(1,325)	(0.0237)
Δ Commute Length	-364.7	0.0223
	(1,163)	(0.0208)
Δ Pct. Utilizing Public Transit	-2,759	0.00567
	(1,735)	(0.0311)
Initial Value	0.0135***	-0.0268***
	(0.00248)	(0.00533)
Pct. Nonresidential	76.02	0.000800
	(113.1)	(0.00194)
Anticipatory Weight	29.09	-0.00252
	(91.69)	(0.00164)
Proximity 520	-100.4	-0.000709
	(131.6)	(0.00236)
Proximity I-90	-6.420	-0.000204
	(97.50)	(0.00173)
Anticipatory Weight X Proximity 520	84.25	0.000823
	(162.8)	(0.00292)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 57 - Effect of Toll on Employment Characteristics, Anticipatory Model with Dummy for Light Rail - Comparison Group II Proximity Measurement

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0381**	-1.31e-08
	(0.0178)	(3.17e-07)
Distance to CBD	1.557	9.86e-05
	(15.39)	(0.000269)
Percent Commuting to CBD	368.2	0.0173
	(973.6)	(0.0159)
Eastside	90.88	0.00165
	(103.6)	(0.00183)
Δ Lag Black	967.5	-0.112
	(12,017)	(0.216)
Δ Lag Income	0.00238	1.49e-07
	(0.00787)	(1.41e-07)
Δ Lag Unemployment	-5,894**	0.0400
	(2,666)	(0.0477)
Δ Lag Poverty	-1,689	0.0304
	(1,695)	(0.0303)
Δ Age	-28.87	-0.000413
	(164.1)	(0.00294)
Δ Education	-808.1	-0.0214
	(1,326)	(0.0237)
Δ Commute Length	-356.5	0.0211
	(1,164)	(0.0208)
Δ Pct. Utilizing Public Transit	-2,763	0.00631
	(1,736)	(0.0311)
Initial Value	0.0135***	-0.0268***
	(0.00248)	(0.00532)
Pct. Nonresidential	75.13	0.000944
	(113.2)	(0.00194)
LR Operational	41.92	-0.00632**
	(158.9)	(0.00284)
Anticipatory Weight	-16.38	0.00433
	(195.2)	(0.00349)
Proximity 520	-101.9	-0.000480
	(131.8)	(0.00236)
Proximity I-90	-6.109	-0.000247
	(97.53)	(0.00173)
Anticipatory Weight X Proximity 520	86.19	0.000529
	(163.0)	(0.00292)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 58 - Effect of Toll on Log of Total Employment, Anticipatory Model - Comparison Group II Proximity Measurement

	Dependent Variable
	Δ Log(Total Employment)
Independent Variable	
Δ Lag Employment Density	-1.01e-06
	(1.89e-06)
Distance to CBD	-0.00275*
	(0.00164)
Percent Commuting to CBD	-0.0782
	(0.104)
Eastside	-0.00343
	(0.0111)
Δ Lag Black	-0.551
	(1.281)
Δ Lag Income	-1.03e-06
	(8.40e-07)
Δ Lag Unemployment	0.0648
	(0.284)
Δ Lag Poverty	-0.240
	(0.181)
Δ Age	-0.0441**
	(0.0172)
Δ Education	-0.420***
	(0.141)
Δ Commute Length	-0.0921
	(0.124)
Δ Pct. Utilizing Public Transit	0.123
	(0.185)
Initial Value	-2.56e-08
	(2.64e-07)
Pct. Nonresidential	0.00603
	(0.0121)
Anticipatory Weight	0.0128
	(0.00978)
Proximity 520	-0.0211
	(0.0140)
Proximity I-90	-0.00630
	(0.0104)
Anticipatory Weight X Proximity 520	0.0154
	(0.0174)
Observations	3,159
Number of tracts	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 59 - Effect of Toll on Employment Characteristics, Contemporaneous Model - Comparison Group II Proximity Measurement		
	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0394**	3.15e-08
	(0.0178)	(3.17e-07)
Distance to CBD	1.168	0.000125
	(15.37)	(0.000269)
Percent Commuting to CBD	355.7	0.0180
	(973.0)	(0.0159)
Eastside	91.19	0.00165
	(103.6)	(0.00183)
Δ Lag Black	354.9	-0.120
	(12,062)	(0.217)
Δ Lag Income	0.00262	1.33e-07
	(0.00787)	(1.41e-07)
Δ Lag Unemployment	-6,036**	0.0408
	(2,663)	(0.0477)
Δ Lag Poverty	-1,636	0.0280
	(1,693)	(0.0303)
Δ Age	-3.040	-0.00224
	(158.6)	(0.00284)
Δ Education	-852.5	-0.0233
	(1,324)	(0.0237)
Δ Commute Length	-440.2	0.0222
	(1,165)	(0.0209)
Δ Pct. Utilizing Public Transit	-2,836	0.00594
	(1,738)	(0.0311)
Initial Value	0.0135***	-0.0268***
	(0.00248)	(0.00533)
Pct. Nonresidential	78.94	0.000713
	(113.1)	(0.00194)
Toll Operational	44.58	-0.00179
	(83.87)	(0.00150)
Proximity 520	-99.91	-0.000422
	(113.0)	(0.00203)
Proximity I-90	-7.891	-0.000173
	(97.48)	(0.00173)
Toll Operational X Proximity 520	125.8	0.000272
	(146.4)	(0.00262)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 60 - Effect of Toll on Employment Characteristics, Contemporaneous Model with Dummy for Light Rail - Comparison Group II Proximity Measurement

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0395**	8.01e-09
	(0.0178)	(3.17e-07)
Distance to CBD	1.144	0.000102
	(15.39)	(0.000269)
Percent Commuting to CBD	354.9	0.0174
	(973.3)	(0.0159)
Eastside	91.18	0.00165
	(103.6)	(0.00183)
Δ Lag Black	363.5	-0.111
	(12,066)	(0.217)
Δ Lag Income	0.00264	1.48e-07
	(0.00788)	(1.41e-07)
Δ Lag Unemployment	-6,035**	0.0421
	(2,664)	(0.0477)
Δ Lag Poverty	-1,633	0.0308
	(1,695)	(0.0304)
Δ Age	-1.425	-0.000671
	(164.6)	(0.00295)
Δ Education	-850.4	-0.0213
	(1,326)	(0.0237)
Δ Commute Length	-439.5	0.0229
	(1,165)	(0.0209)
Δ Pct. Utilizing Public Transit	-2,836	0.00617
	(1,738)	(0.0311)
Initial Value	0.0135***	-0.0268***
	(0.00248)	(0.00533)
Pct. Nonresidential	79.13	0.000908
	(113.2)	(0.00194)
Toll Operational	-2.994	-0.00292**
	(81.53)	(0.00146)
Proximity 520	46.68	0.000261
	(101.6)	(0.00182)
Proximity I-90	-99.71	-0.000234
	(113.1)	(0.00203)
Toll Operational X Proximity 520	-7.958	-0.000235
	(97.51)	(0.00173)
Observations	125.6	2.22e-05
Number of tracts	(146.6)	(0.00263)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 61 - Effect of Toll on Log of Total Employment, Contemporaneous Model - Comparison Group II Proximity Measurement

	Dependent Variable Δ Log(Total Employment)
Independent Variable	
Δ Lag Employment Density	-1.21e-06
	(1.89e-06)
Distance to CBD	-0.00293*
	(0.00163)
Percent Commuting to CBD	-0.0794
	(0.103)
Eastside	-0.00344
	(0.0110)
Δ Lag Black	-0.0503
	(1.283)
Δ Lag Income	-8.69e-07
	(8.37e-07)
Δ Lag Unemployment	0.0131
	(0.283)
Δ Lag Poverty	-0.246
	(0.180)
Δ Age	-0.0322*
	(0.0169)
Δ Education	-0.434***
	(0.141)
Δ Commute Length	-0.145
	(0.124)
Δ Pct. Utilizing Public Transit	0.128
	(0.185)
Initial Value	-2.59e-08
	(2.63e-07)
Pct. Nonresidential	0.00699
	(0.0120)
Toll Operational	0.0380***
	(0.00892)
Proximity 520	-0.0115
	(0.0120)
Proximity I-90	-0.00655
	(0.0104)
Toll Operational X Proximity 520	-0.00291
	(0.0156)
Observations	3,159
Number of tracts	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 62 - Effect of the Light Rail and Toll on Employment Characteristics, Anticipatory Model - Comparison Group II

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public Jobs
Independent Variable		
Δ Lag Employment Density	-0.0384**	3.33e-08
	(0.0177)	(3.16e-07)
Δ Lag Black	3,345	-0.203
	(12,174)	(0.219)
Δ Age	14.67	-0.000966
	(161.9)	(0.00289)
Δ Education	-700.3	-0.0227
	(1,325)	(0.0237)
Δ Lag Income	0.000905	1.36e-07
	(0.00788)	(1.41e-07)
Δ Lag Unemployment	-5,697**	0.0464
	(2,666)	(0.0477)
Δ Lag Poverty	-1,815	0.0327
	(1,694)	(0.0303)
Δ Commute Length	-447.3	0.0168
	(1,165)	(0.0208)
Δ Pct. Utilizing Public Transit	-2,472	0.0151
	(1,740)	(0.0311)
Δ Home Price	-0.000181*	2.24e-09
	(0.000101)	(1.81e-09)
Initial value	0.0168***	-0.0227***
	(0.00280)	(0.00540)
Distance to CBD	5.766	0.000104
	(15.45)	(0.000272)
Distance to freeway	6.503	-0.000527
	(32.80)	(0.000586)
Percent Commuting to CBD	902.5	0.0185
	(978.1)	(0.0166)
Pct. Nonresidential	73.31	0.00147
	(114.3)	(0.00197)
Eastside	110.9	0.00108
	(103.5)	(0.00184)
Toll Anticipatory Weight	23.78	-0.00273*
	(91.88)	(0.00164)
Proximity 520	-69.02	-0.000925
	(133.1)	(0.00238)
Proximity I-90	10.72	3.14e-05
	(98.70)	(0.00175)
Toll Anticipatory Wgt. X Proximity 520	17.36	0.00107
	(164.7)	(0.00294)
Δ Anticipatory X Retro X Qtr-Mile	-24,360***	-0.00253
	(6,643)	(0.103)
Δ Anticipatory X New X Qtr-Mile	-563.9	-0.366***
	(4,612)	(0.0835)
Observations	3,159	3,159
Number of tract	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 63 - Effect of the Light Rail and Toll on Employment Characteristics, Contemporaneous Model - Comparison Group II

	Dependent Variable	
	Δ Employment Density	Δ Pct. Public
Independent Variable		
Δ Lag Employment Density	-0.0729***	1.27e-07
	(0.0176)	(3.12e-07)
Distance to CBD	3.395	4.08e-05
	(15.05)	(0.000262)
Percent Commuting to CBD	685.9	0.0137
	(953.1)	(0.0156)
Eastside	96.00	0.000982
	(101.4)	(0.00179)
Δ Lag Black	764.6	-0.140
	(11,809)	(0.211)
Δ Lag Income	0.00151	1.14e-07
	(0.00771)	(1.37e-07)
Δ Lag Unemployment	-6,008**	0.0427
	(2,607)	(0.0464)
Δ Lag Poverty	-1,720	0.0247
	(1,658)	(0.0295)
Δ Age	62.60	-0.000386
	(155.5)	(0.00277)
Δ Education	-710.2	-0.0139
	(1,297)	(0.0231)
Δ Commute Length	-416.5	0.0184
	(1,141)	(0.0203)
Δ Pct. Utilizing Public Transit	-1,335	-0.000470
	(1,706)	(0.0304)
Initial Value	0.0199***	-0.0190***
	(0.00249)	(0.00522)
Pct. Nonresidential	58.81	0.000539
	(110.7)	(0.00189)
Toll Operational	49.81	-0.00208
	(82.11)	(0.00146)
Proximity 520	-87.16	-0.000457
	(110.6)	(0.00198)
Proximity I-90	-12.40	0.000789
	(95.55)	(0.00169)
Toll Operational X Proximity 520	44.36	-0.000155
	(143.5)	(0.00256)
Δ Station Operational X Retro X Qtr-Mile	-15,812***	0.0380
	(1,350)	(0.0234)
Δ Station Operational X New X Qtr-Mile	-1,344	-0.356***
	(1,502)	(0.0269)
Observations	3,159	3,159
Number of tracts	351	351

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix – Data

Data Appendix

Variable	Source	Impute[3]	Years	Inclusion
African American[1]	Washington State Small Area Estimates Program	No	2004-2014	Dependent variable, Independent variable
Average Age	Washington State Small Area Estimates Program	No	2004-2014	Dependent variable, Independent variable

The Washington State Small Area Estimates Programs provides figures for the total population within 17 age bins of increments of five years and one bin for individuals who are 85 and older. To determine a tract's average age, I find a weighted average by population of the median age within each bin. I assign a value of 92 to the bin of individuals aged 85 and older.

Commuting to CBD	2000 Census Transportation Planning Package	No	2000 applied to all panel years.	Independent variable

To determine the percentage of a tract's commuters who travel to the CBD for employment, I first create a polygon in ArcGIS that delineates the Seattle CBD. I then calculate the percentage of each tract that lies within this polygon. *Commuting to CBD* is calculated as the weighted total commuters whose place of work lies within the CBD divided by all commuters within the tract. Since most tracts within the CBD are not encompassed entirely within the CBD polygon, I multiply the commuters from each tract traveling to a CBD tract by the percentage of the CBD tract that falls within the polygon. A commuter is defined as all workers 16 years and older who report being employed outside the home during the Census 2000 Reference Week.

Commute Length	2000 Census and 2009 – 2014 ACS	2004 – 2008 are imputed.	2004-2014	Independent variable

The total number of commuters from each tract with a given commute length are provided within five commute length bins of ten-minute increments and one bin with no upper bound (60 minutes or more). I first take the median of each bin and then take a weighted average of the bin medians, contingent on the percentage of commuters with the given commute length. I assign 75 minutes as the value for computation for the bin of '60 minutes or more.' Numbers reflect 2000 Census SF3 sample data (P031) and ACS five-year estimates (B08101).

Education	2000 Census and 2009 – 2014 ACS	2004 – 2008 are imputed.	2004-2014	Dependent variable, Independent variable

Education is measured as the percentage of a tract's inhabitants with at least a Bachelor's degree. Numbers reflect 2000 Census SF3 sample data (P037) and ACS five-year estimates (S1501).

Employment*	Puget Sound Regional Council	No	2004-2014	Dependent variable, Independent variable

Employment figures represent total jobs per tract in March of each year, as reported to the Washington State Employment Security Department. Temporary and part-time jobs are included.

Data Appendix (continued)				
Home price	2000 Census and 2009 – 2014 ACS	2004 – 2008 are imputed.	2004-2014	Independent variable

Home Price represents the price asked for homes for sale within each tract. The Census and ACS data on housing prices are provided in thirteen bins of $10,000, four bins of $25,000, two bins of $50,000, two bins of $100,000, two bins of $250,000 and one bin of $1,000,000 and greater. To determine a concrete data point for each tract, I take the median of each bin and multiply the number of homes for sale corresponding to each bin by this midpoint. I conduct this procedure across all bins for each tract and then sum the value of all bins to obtain an approximate value of all homes on the market for each tract. I then divide out by the number of homes to find the mean asking price for a home within the given year. Given that the highest priced bin has no upper bound, I am unable to assign a midpoint. In order to account for these homes in the analysis, I assign a value of $3,500,000 for all homes in the highest bin. This procedure discounts homes with immense value but, given their relative rarity, it is unlikely to impact the results. Numbers reflect 2000 Census SF3 sample data (H087) and ACS five-year estimates (B25085). Prices are adjusted to 2014 values.

Total Housing units	Washington State Small Area Estimates Program	No	2004-2014	Dependent variable
Income[2]	2000 Census and 2009 – 2014 ACS	2004 – 2008 are imputed.	2004-2014	Independent variable

Income represents the median income in a tract. Numbers reflect 2000 Census SF3 sample data (P053) and ACS five-year estimates (S1093). Values are adjusted to the 2014 price level.

Nonresidential	King County GIS Data Portal and Snohomish County's website	No.	2013 applied to all panel years.	Independent variable

A nonresidential assignment in ArcGIS indicates a zoning designation allows for any type of commercial presence as defined in King County's Land Use Code, SMC Title 23 and the Snohomish County Code, Title 30 Table 30.21.020. Some designations allow for both residential and nonresidential uses: these parcels are assigned to both the residential and nonresidential categories within ArcGIS.

Total Population	Washington State Small Area Estimates Program	No	2004-2014	Dependent variable
Population below FPL[2]	2000 Census and 2009 – 2014 ACS	2004 – 2008 are imputed.	2004-2014	Independent variable

Numbers reflect 2000 Census SF3 sample data (P087) and ACS five-year estimates (S1701).

Public Sector Jobs	Puget Sound Regional Council	No	2004-2014	Dependent variable

Public employment figures represent total public-sector jobs per tract in March of each year, as reported to the Washington State Employment Security Department. Temporary and part-time jobs are included.

Public Transit Users	2000 Census and 2009 – 2014 ACS	2004 – 2008 are imputed.	2004-2014	Independent variable

Numbers reflect 2000 Census SF3 sample data (P030) and ACS five-year estimates (B08101).

Data Appendix (continued)				
Residential	King County GIS Data Portal and Snohomish County's website	No.	2013 applied to all panel years.	Independent variable

A residential assignment in ArcGIS indicates a zoning designation allows for any type of residential inhabitance as defined in King County's Land Use Code, SMC Title 23 and the Snohomish County Code, Title 30 Table 30.21.020. Some designations allow for both residential and nonresidential uses: these parcels are assigned to both the residential and nonresidential categories within ArcGIS.

Unemployment[2]	2000 Census and 2009 – 2014 ACS	2004 – 2008 are imputed.	2004-2014	Independent variable

Unemployment reflects the unemployment rate of the population aged 16 years and older. Numbers reflect 2000 Census SF3 sample data (QT-P24) and ACS five-year estimates (S2301).

1. Lagged one period when used as independent variable
2. Lagged one period
3. I impute values for 2004 through 2008 using a weighted average of the variable's 2000 Census value and the variable's 2009 ACS value. Values for 2009 and later reflect the ACS data.

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Vita

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