National Street Improvements Study: Findings from Seattle

1. Introduction

Across the country, policymakers and planning departments are making cities more livable by better accommodating people who walk and bike. Improving streets and upgrading transportation infrastructure often require reducing on-street parking or traffic lanes. While studies have shown how such upgrades improve traffic safety and mobility for city residents, the question remains how such infrastructure improvements affect economic outcomes.

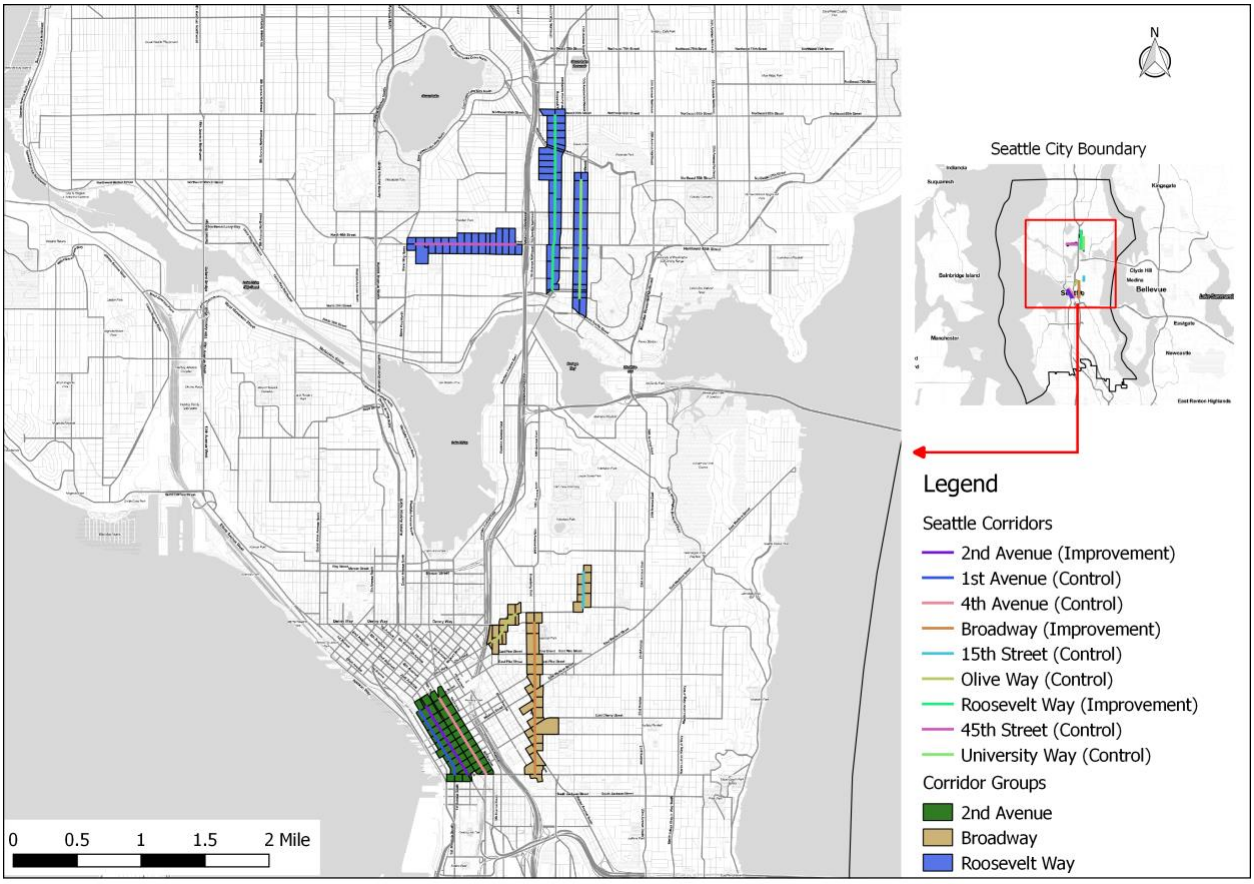


Figure 1-1. Seattle Corridor Map

Active transportation advocates often assert that the improvement of active transportation infrastructure will largely increase the number of customers that can arrived via alternative modes in addition to automobiles, and, ultimately, lead to greater revenue and employment growth. While there is some suggestive evidence of this, ranging from self-supported surveys of business owners (Flusche 2012; Jaffe 2015; Stantec Consulting 2011) to consumer behavior surveys (Clifton et al. 2012; Bent et al. 2009) before and after the

installation of active transportation projects. Recently, a few studies have approached this research question by comparing sales tax or employment trends over time for on the improved blocks (NYCDOT 2013; Rowe 2013; Poirier 2017). However, while some researchers have started employing quasi-experimental methodologies (Dill et al. 2014; Yu et al. 2018), the majority have been descriptive or exploratory in nature, or have been limited to case studies within specific urban areas. The validity concerns and lack of consistent data backing many of the previous studies have given the pause and reason to call for additional research and evidence to address the data and methodological concerns.

This study will attempt to answer to what extent these types of corridor-level street improvements impact economic activity and business vitality in the immediate vicinity. Utilizing systematic data sources and methodologies across multiple cities and corridors, we examine, in particular, how do street improvements impact retail sales and employment?

Seattle has conducted many street improvement projects in past years, such as bike lane installations, road diets, etc. This report explores three recent street improvement corridors, which are Second Avenue, Broadway and Roosevelt Way, to understand the economic and business impact of these active transportation infrastructure investments. However, as Roosevelt Way installed the bike lane in 2016, there is not enough data to evaluate the post-construction performance, thus we exclude it from corridor analysis.

2. Data Sources/Methodology

2.1 Data Sources

For this study, we used multiple data sources to estimate the effect of new bike lane infrastructure investment. Because this project makes use of a variety of different data sources, it required collaboration between the research team and representatives from multiple agencies/departments. Our principal contact was with the Minneapolis Department of Public Works. Sales tax data was provided by the Minneapolis Community Planning and Economic Development (CPED) department; QCEW data was provided by the Minnesota Department of Employment and Economic Development; and LEHD data was publicly available at United State Census Bureau.

First, we used the Longitudinal Origin-Destination Employment Statistics (LODES) data set from the **Longitudinal Employer-Household Dynamics Dataset** (LEHD). It integrates existing data from state-supplied administrative records on workers and employers with existing census, surveys, and other administrative records to create a longitudinal data system on U.S employment. This data set tracks Workplace Area Characteristics (WAC), census blocks where people work as opposed to where workers live, for all the census blocks between 2002 and 2015 for most of the states in the US. As such, LEHD provides geographically granular detail about American's jobs, workers and local economies, allowing us to examine employment by broad industry sector, wage and educational attainment. Some disadvantages of the LODES data set are that in order to guarantee confidentiality block level data is "fuzzed" so the numbers are not exactly the number of jobs, but they are accurate estimates. Additionally, though we get industrial data, it is only provided at the most general level (the equivalent of two digit NAICS codes) so we are unable to isolate specific retail or service employment such as restaurant workers. That being said, the LEHD data set is comprehensive, offers unprecedented geographic detail, and longitudinal allowing for consistent comparisons over time.

This report also takes advantage of establishment level **Quarterly Census of Employment and Wages (QCEW) data**. The QCEW gives us address level data on individual establishments as well as detailed employment information, allowing for more accurate pinpointing of the geographic location of businesses and industrial classifications. However, the individual QCEW data is confidential and requires special permission from the state in order to use it, and has additional data use restrictions. Due to confidential restriction, we only got the corridor level retail and food & accommodation employment data aggregated by Puget Sound Regional Council. In particular, employment figures were suppressed if there were less than three employers in certain NAICS code/year in the corridors. These aggregated numbers correspond closely to the LEHD codes used in the report, but with the advantage that the numbers are not "fuzzed" for confidentiality concerns.

Sales tax data is collected as the primary data source to allow us to estimate a more sensitive measure of economic activity than employment (as the decision to hire or fire employees for a firm is often an expensive one, and thus we would expect employment to be a delayed response to changes in economic activities). Some drawbacks of sales tax data

are that some states do not have a sales tax or, in states or cities that do have one, the sales tax data is not broken down by specific industry and it is difficult to accurately parse out accurate figures. But the benefits of sales tax data largely outweigh these issues and do offer a more sensitive metric than employment. Washington has a general 6.5% sales tax for all businesses with a variety of additional taxes dependent upon use and the city/county a particular establishment is located. For example, Seattle has an additional 3.6% retail sales tax. However, certain food categories, prescription drug among others are exempted from tax collection, which may hamper the ability of sales tax data to accurately reflect all retail business vitality. The aggregated sales tax data by corridors are provided by Department of Revenue. However, we cannot distinguish particular industry sectors and separated control corridors using the data. The report below only shows the findings from LEHD and QCEW data.

2.2 Methodology

We applied three methods in order to isolate the impact of street improvements while controlling for other economic and regional factors. The methods are an integrated trend analysis (following the NYCDOT study(2013)), a difference-in-difference approach, and an interrupted time series analysis. The time frame used in the analysis for LEHD data is 2004-2015, and 2008-2017 for QCEW data.

2.2.1 Corridor Comparison Selection

In order to properly isolate the effect of the street improvements, we must identify treatment corridors (corridors where the street improvement occurred) and control corridors (corridors that are similar to the treatment corridors except they remain unimproved). Treatment corridors are corridors where new bike or pedestrian related improvements were installed, ideally made up of a minimum of 10 adjacent, or intersecting, census blocks with a minimal number of retail and food service jobs. Additionally, we chose street improvement corridors installed between 2008 and 2013 in order to guarantee we have sufficient data (at least 3 data points pre- and post-treatment) to track pre- and post-treatment economic trends.

Once corridors are selected based on these criteria, further testing is conducted to discern the level of similarity between treatment and control corridors. We compare similarity in two broad aspects: transportation/geography and business activity levels. In terms of transportation and geographic characteristics, the corridors should ideally be geographically close to each other, with similar street classifications, travel volumes and relative location/role within the city's road network.

The level of business activity in both retail and food services industries should be similar on treatment and control corridors, and the general patterns of growth prior to the street improvement should be similar as well. Furthermore, the ratio of business jobs (defined as the sum of retail and food service industry jobs) to overall number of jobs on the treatment and control corridors should be at similar levels. These similarity tests include quintile comparisons and statistical tests of the corridor employment to citywide employment

ratios and average block level employment on the street improvement corridor and the proposed corresponding control corridors.

Specifically, t-tests are performed on three metrics at the census block level: (a) "business" employment, the sum of retail and food employment; (b) a census block level "business share" metric that is the number of business employment over the sum of other services industry employment such as professional/scientific services, public administration and educational services; alternatively, another business share metric is calculated that includes a smaller share of services employment (including professional/scientific services, administrative/waste management services and arts/accommodation services). As long as one of the business metrics indicates similarity between treatment and control corridors, we consider similarity between the two corridors; and (c) a pre-construction annual employment growth rate.

Table 2-1. Corridor comparison indicators and methods

Comparison Category	**Indicators**	**Method**
Transportation/ Geography	Geography proximity	Researcher judgement
	Street classification (travel volume)	
	Role in road network	
Business activity	Job percentile brackets to regional average	Statistical test (t-test)
	Business jobs share compared to overall jobs	
	Pre-construction employment growth rate	

2.2.2 Aggregated Trend Comparison

This first method follows the previous NYCDOT study (NYCDOT 2013), aiming to examine whether the treatment corridors tend to have better business performance than comparison corridors after street improvements. The approach compares the trends of treatment and control corridors in addition to city-wide trends over the full time period for which we have data. If treatment corridors show greater growth rates in employment or sales tax receipts, or a jump in the level of employment or sales, then that would represent a positive impact of the street improvement on business activities. This method is easy to follow and represents the aggregated trend of business activities. However, it lacks the rigor of econometric estimates and statistical tests that explicitly test whether or not the street improvement caused the changes.

We present both absolute and indexed values for all variables. Indexed values are useful when you need to compare values on different scales. For some corridors the differences in employment or sales tax is large and it is not possible to accurately compare those to smaller corridors without indexing. This is especially important for something like sales tax

where some corridors have large amounts of taxable sales due to being on a major travel corridor or having a large anchor retailer like a department store.

2.2.3 Difference-in-Difference (DID)

The second method aims to estimate the difference in business vitality of pre- and post-improvement periods between treatment and control corridors within the same time period. This is known as a difference-in-difference (DID) approach (Angrist et al. 2009). It is a designed to answer the "but for" question of what a corridor's economic trajectory would look like, had the streets not been improved. It requires data from pre/post intervention such as panel data (individual level data overtime) or cross-sectional data (individual or group level). The approach looks at the change in the variable of interest in the treatment corridor before and after it is treated. In this case this means looking at some time period before and after a street improvement, and comparing the economic indicators to the control corridor which has not received the street improvement. The difference in growth trajectories between the two periods will give an unbiased estimate of the effect of the treatment. DID is a useful quasi-experimental technique when true randomized experiments are not possible. This approach removes biases in the second period comparisons between the treatment and control corridors that could be the result of inherent differences between these corridors, as well as biases from comparisons over time in the treatment corridor that could be the result of prior trends. A key assumption of DID estimate is that the differences between control group and treatment group would have remained constant in the absence of treatment.

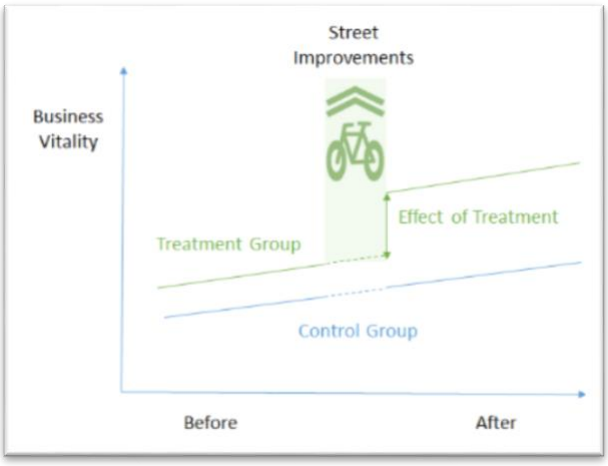


Figure 2-1. Illustration of DID method

DID is a linear modeling approach and its basic formula is expressed as:

$$Y_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 A_{it} + \beta_3 T_{it} A_{it} + \varepsilon_{it}$$

Y_{it} is the observed outcome in corridors i and t (in this case change in employment or sales tax revenue); T_{it} is a dummy variable set to 1 if the observation is from the treatment corridor, or 0 if the observation is from the control corridor; A_{it} is a dummy variable set to 1 if the observation is from the post-treatment period; β_3 is the DID estimator of the

treatment effect, specified as the ***prepost:corridor_name*** coefficient in our analysis. Typically, the DID estimator of interest is β_3, and if it is estimated to be statistically significant and positive, then this suggests a positive causal effect of the street improvement on the economic indicator in question. Conversely, if the estimate is significant and negative, then that indicates a negative effect of the improvement. Finally, a non-significant result indicates the improvement had no statistically discernible effect.

2.2.4 Interrupted Time Series (ITS)

Interrupted time series (ITS) is an econometric technique that estimates how street improvements impact corridor economic vitality from a longitudinal perspective. This approach tracks the treatment corridor over time and estimates the impact from the street improvement by identifying changes in its growth trend after the treatment (Lopez Bernal et al., 2016). If the treatment has a causal impact, the post-intervention economic indicators will have a different level or slope than the pre-intervention data points. In our research, interrupted-time series will be used to distinguish differences in economic level or growth before and after a specific time period when a street improvement is constructed, such as a new buffered or protected bike lane.

One advantage of ITS is that it allows for the statistical investigation of potential biases in the estimate of the effect of the intervention. Given the longitudinal nature of the test, ITS requires a significantly larger amount of data in order to accurately estimate a real effect on the growth trend.

The interrupted time-series analysis equation can be expressed as:

$$Y_t = \beta_0 + \beta_1 T_t + \beta_2 X_t + \beta_3 T_t X_t + \varepsilon_{it}$$

Y_t is the observed business outcome in time period t; T_t indicates the number of quarters from start to finish of the series; X_t is the treatment dummy variable taking on values of 0 in the pre-intervention period and 1 in the post-intervention period; β_0 is the model intercept or baseline level at t = 0; β_1 represents the estimated slope (or growth rate) during the pre-intervention period, which we specify as the ***ts_year*** coefficient; β_2 represents the level change following the intervention, specified as the ***prepost*** coefficient; and β_3 indicates the slope change following the intervention, which is the ***ts_year:prepost*** coefficient. A positive and statistically significant β_2 coefficient tends to suggest a positive causal effect on the level of business vitality immediately following the street improvement. A positive and statistically significant β_3 coefficient would suggest a positive causal effect on the growth in business vitality over time.

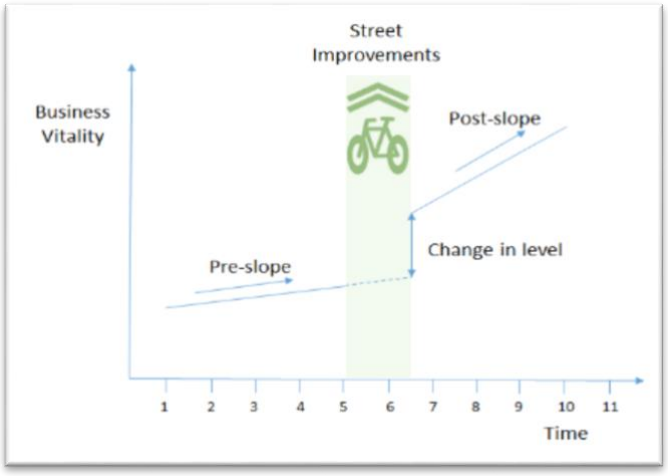


Figure 2-2. Illustration of ITS method

In conclusion, aggregated trend analysis and DID analysis both utilize control corridors to determine the impacts of the street improvement corridor, while the ITS analysis uses multiple time points on the street improvement corridor itself to pinpoint economic outcomes. In general, the ITS analysis provides more robust results than the other two methods, since it is less likely to be affected by the selection of control corridors. However, this method generally requires more data points post-intervention to achieve meaningful and valid impact estimations. The DID approach is heavily dependent on finding comparable control corridors (which may not always exist), so the analytical results may be weakened when appropriate corridors cannot be identified.

Additional data points after the completion of street improvements may help to provide further validity and rigor to the analysis of resulting economic outcomes. Moreover, further contextual information about the street improvement corridor, such as quality or level of the street improvement, number of parking spots eliminated, and subsequent bicycle ridership or pedestrian increases, would help to better understand the linkages between the improvements and potential impacts on business vitality. Extending this research to more closely examine the changes and shifts in industrial patterns will be valuable as well.

3. Corridor Comparisons

Our first test in corridor comparability is to compare the count of jobs, retail, and food service industry jobs per block on the corridors to block figures for the city of Seattle as a whole. This is allows us to have a broad understanding of the relative job density of the corridors. This serves two purposes: first, it gives us a quick estimate of the range of employment in each industry on the corridors; and second, it shows how similar the corridors are to each other in terms of economic activities. Finally, we perform a t-test (a statistical test designed to measure if the means of two different groups are statistically similar) on the number of economic indicators, which offers a more rigorous test of the comparability of the corridors. All of the following figures and tables use employment data from the LEHD in the year prior to the street improvement project as the base year for comparison.

3.1 Second Avenue

Figure 3-1. Second Avenue Corridor

Our first corridor group consists of the Second Avenue, First Avenue and Fourth Avenue corridors in downtown Seattle. Although First Avenue corridor overlaps half of the blocks with the treatment corridor, we still include it at this stage to examine the similarity to Second Avenue corridor.

The following table shows total, retail, and food employment for Second Avenue, First Avenue and Fourth Avenue and the city based percentile rank of the corridors. All corridors

are in the top 10% of the city in terms of the number of total employment. In terms of retail, First Avenue has slightly higher employment than Second Avenue, while Fourth Avenue has similar employment numbers, and all in top 25% percentile. There is slight difference in food service sector, the treatment corridor Second Avenue is in top 15% percentile, while the control corridors are in top 10% percentile.

Table 3-1. Second Avenue and Control Corridors Employment

	Employment per block			Percentiles		
Corridor	Total	Retail	Food	Total	Retail	Food
2nd Ave.	1135	14	42	95-100	75-80	85-90
1st Ave.	711	22	60	90-95	80-85	90-95
4th Ave.	771	14	57	95-100	75-80	90-95

Statistically testing of all three metrics returned non-significant results, except the growth rate between treatment corridor and Fourth Avenue, meaning that there is not a statistically significant difference in the mean employment levels between the two control corridors and treatment corridor. This means that the control corridors are comparable and are appropriate for our analysis.

3.2 Broadway Street

Figure 3-2. Broadway Corridor

Our second treatment corridor is Broadway Street, which started its installation of a protected bike lane in 2013, and completed the installation in spring of 2014. It has two control corridors: 15th Ave East, and East Olive Way. They locate in Pike/Pine or Capital Hill neighborhoods, close to Downtown core retail area.

The following table shows total, retail, and food employment for Broadway Street, 15th Ave East, and East Olive Way corridors, and the city based percentile rank of the corridors. Broadway has much more employment than the other comparison corridors. However, with respect to our interested business employment, the corridors are at similar level. 15th Ave East has slight higher percentiles in both retail and food sectors than the treatment corridor, while E Olive Way has slightly less food employment with very small amount of retail employment.

Table 3-2. Broadway Corridor and Control Corridors Employment

	Employment per block			Percentiles		
Corridor	Total	Retail	Food	Total	Retail	Food
Broadway	387	16	15	90-95	80-85	70-75
15th Ave E	88	31	27	65-70	85-90	80-85
E Olive Way	30	2	11	40-45	45-50	60-65

In terms of 15th Ave E, the statistically testing of employment number and growth rate before construction metric returned non-significant result, indicating that there is no statistically significant difference in the mean employment per block and growth rate between the two corridors. However, the "business share" metrics test suggests significant difference between treatment corridor and 15th Avenue East. The large share of other service jobs in treatment corridor might influence the impact of bike facility, since the might be confounding effect from other services to retail employment rather than bike lane installation. But given the similarity in business employment amount, the 15th Ave E corridors are still comparable and are appropriate for further analysis.

In terms of East Olive Way, although there is significant difference in retail employment between treatment corridor and E Olive Way, the general business vitality are similar, after taking into account of food sector. The statistically testing of business share metric and growth rate metric both returned non-significant results, indicating that there is no statistically significant difference in the employment metrics between the street improvement and control corridors. Therefore, we conclude E Olive Way is comparable and appropriate for our analysis.

3.3 Roosevelt Way

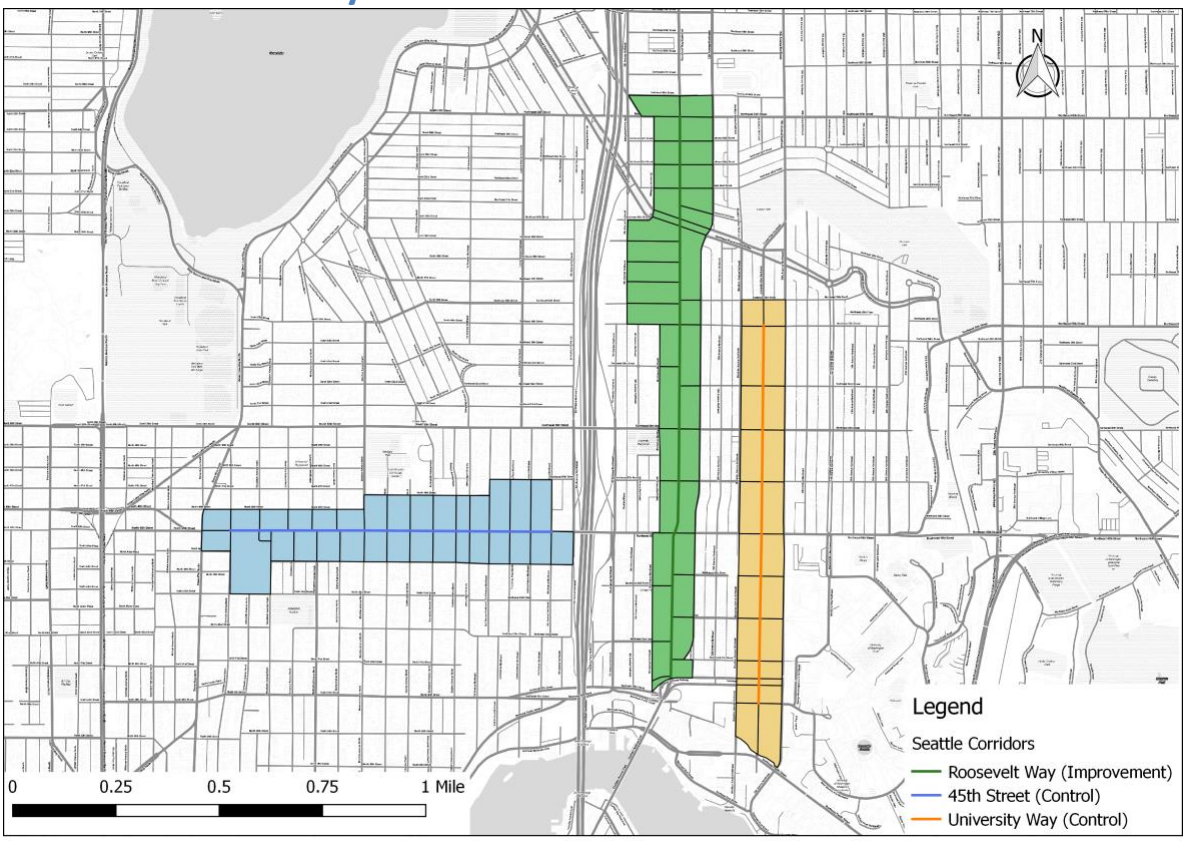


Figure 3-3. Roosevelt Way Corridor

Our third treatment corridor is Roosevelt Way, and it has two control corridors: University Way and N 45th St. They all locate in North Seattle, close to University District.

The following table shows total, retail, and food employment for Roosevelt Way, University Way, and 45th St corridors, and the city based percentile rank of the corridors. Compared with treatment corridor, Roosevelt Way, University Way corridor has similar amount of retail employment, while they are both between 85-90 percentiles. But University Way has more food service jobs than Roosevelt Way. Although 45th Street has similar food service employment as Roosevelt Way, it has less retail jobs. In general, both the two control corridors are comparable with Roosevelt Way to some extent.

Table 3-3. Roosevelt Way Corridor and Control Corridors Employment

	Employment per block			Percentiles		
Corridor	Total	Retail	Food	Total	Retail	Food
Roosevelt Way	74	30	10	60-65	85-90	60-65
University Way	120	39	37	70-75	85-90	85-90
45th St	50	11	15	50-55	70-75	65-70

In terms of University Way, statistically testing shows University Way has similar business and retail employment jobs, but it has significant more food service employment than the improvement corridor. It arise the caveat that the impact of bike lane on food service might be different between the two corridors. Both "business share" metrics t-tests indicate similarity between the two corridors.

In terms of 45th Street, statistically testing of all three metrics returned non-significant results, indicating that there is no statistically significant difference in the employment metrics between the street improvement and control corridors. This means that the corridors are comparable and are appropriate for the purposes of our analysis.

3.4 Corridor Comparison Summary

The following table shows a summary of the corridor comparison analysis for all treatment and control corridor groups, with nine comparability indicators for each group. In terms of Second Avenue improvement corridor, the control corridor is very similar and comparable in most aspects, except retail employment growth rate. This also brings about the caveat of accurate estimation of aggregated trend analysis and DID analysis. With respect to Broadway corridor, two control corridors are equally comparable to the treatment corridor, although there is relatively lower and less vibrate retail activities in East Olive Way. For Roosevelt Way corridor, NE 45th St corridor is a perfect control corridor, while University Way corridor has some differences in terms of lower street classification and more food services due to proximity to University of Washington. While the bike lane installed on Roosevelt Way in 2016 is a good candidate for this type of analysis, it is excluded from the corridor analysis due to insufficient data for post-construction evaluation at this time.

Table 4. Corridor Comparison Summary

Treatment corridor	Indicator		**Second Avenue**		**Broadway Street**		**Roosevelt Way**	
Control corridor			Fourth	First	15th Ave	Olive	University	45th St
Transportation/ Geography	Geographic Proximity		✓	✓	✓	✓	✓	✓
	Street Classification		✓	✓	✓	✓	x	✓
	Role in Street Network		✓	✓	✓	✓	✓	✓
Business Activity	Job Density Percentile	retail	✓	✓	✓	x	✓	✓
		food	✓	✓	✓	✓	x	✓
	Share of Business Jobs		✓	✓	x	✓	✓	✓
	Employment Growth Rate	retail	x	✓	✓	✓	✓	✓
		food	✓	✓	✓	✓	✓	✓

4. Data Analysis

4.1 Second Avenue Corridor

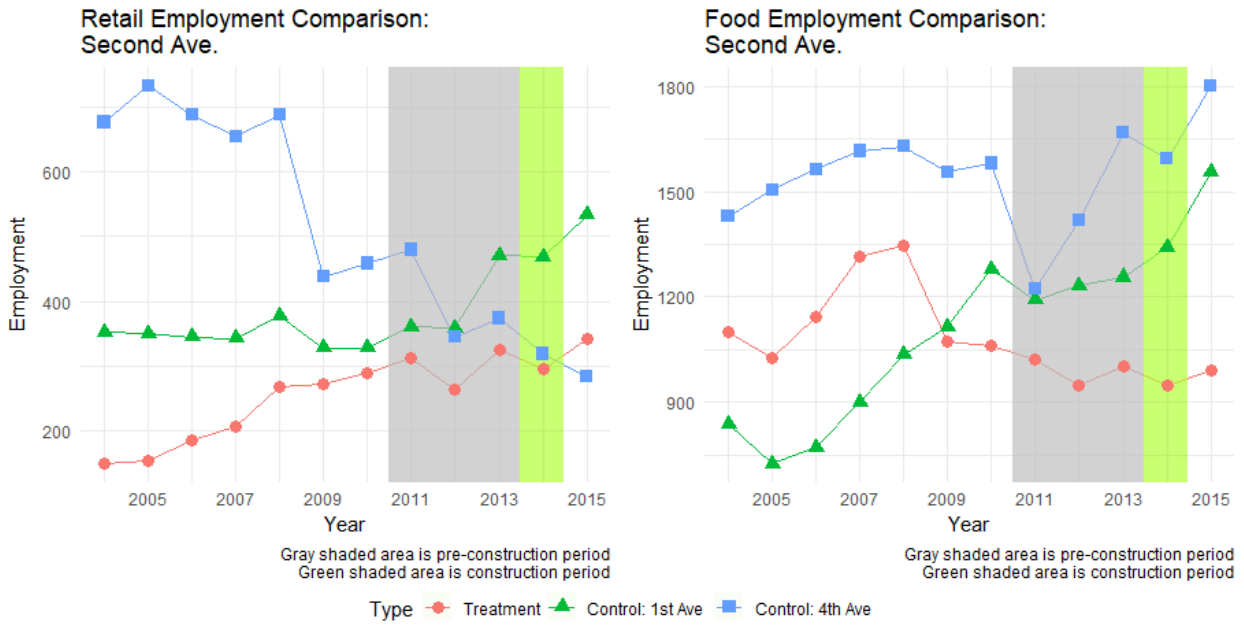
4.1.1 Aggregated Trend Analysis

4.1.1.1 LEHD Data

On Second Avenue, retail employment trend of the three corridors varies among time. Before 2009, the improvement corridor experienced a rapid increase in retail employment, while First Avenue remained relatively flat and Fourth Avenue corridor started with high level of employment and dropped significantly in 2009. The bike facility installation has just taken place in 2014. The newest employment data for LEHD is in 2015. Therefore, although the retail employment increases after bike lane installation, there is not much data to support the after-intervention trend. The increase of retail after bike lane installation on Second Avenue needs more data to justify the trend of the impact.

In terms of food service employment, both control corridors generally grow faster before street improvement than treatment corridor. All three corridor shows increases in food employment in 2015, but more data in later years are needed to verify the trend.

The indexed plots below reflect more clear employment trend. In general, it is consistent with the above trend that retail employment in treatment corridor increased after street improvement, which exceed Fourth Avenue but slower than First Avenue and city average level. The food service employment also increase after street improvement, but slower than other two corridors and city average. However, it is unclear whether the growth on Riverside Avenue can be attributed to the street improvement at this stage, and additional data points in later years are necessary to verify the trend.



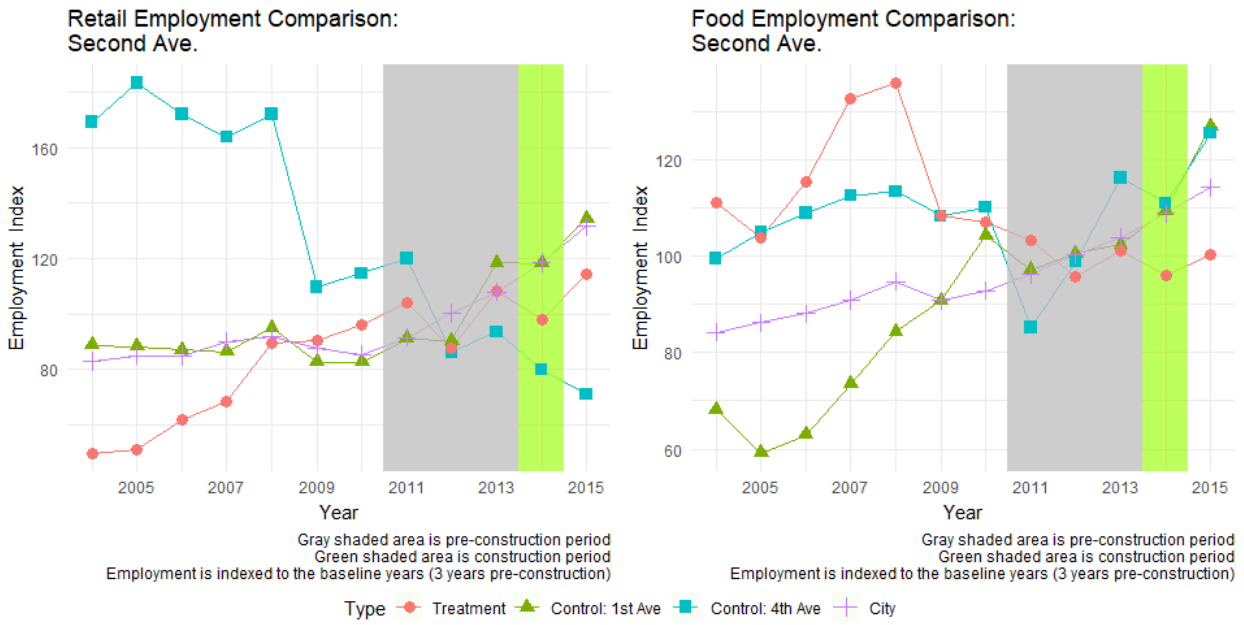


Figure 4-1. Second Avenue Employment Comparison (LEHD)

4.1.1.2 QCEW Data

QCEW data has more recent data points than LEHD, which provides more convincing trend of business employment trend after street improvement. As shown in the figure below, although there is a big jump in retail employment in treatment corridor right after street improvement, the retail employment keeps dropping down after that. However, the overall retail employment level is largely increased after street improvement than pre-construction period.

In terms of food employment, we can observe a significant drop of food employment during street improvement year, but it quickly recovered after street improvement with robust growth. However, the food employment in treatment corridor still grew slow than one of the control corridor – First Avenue.

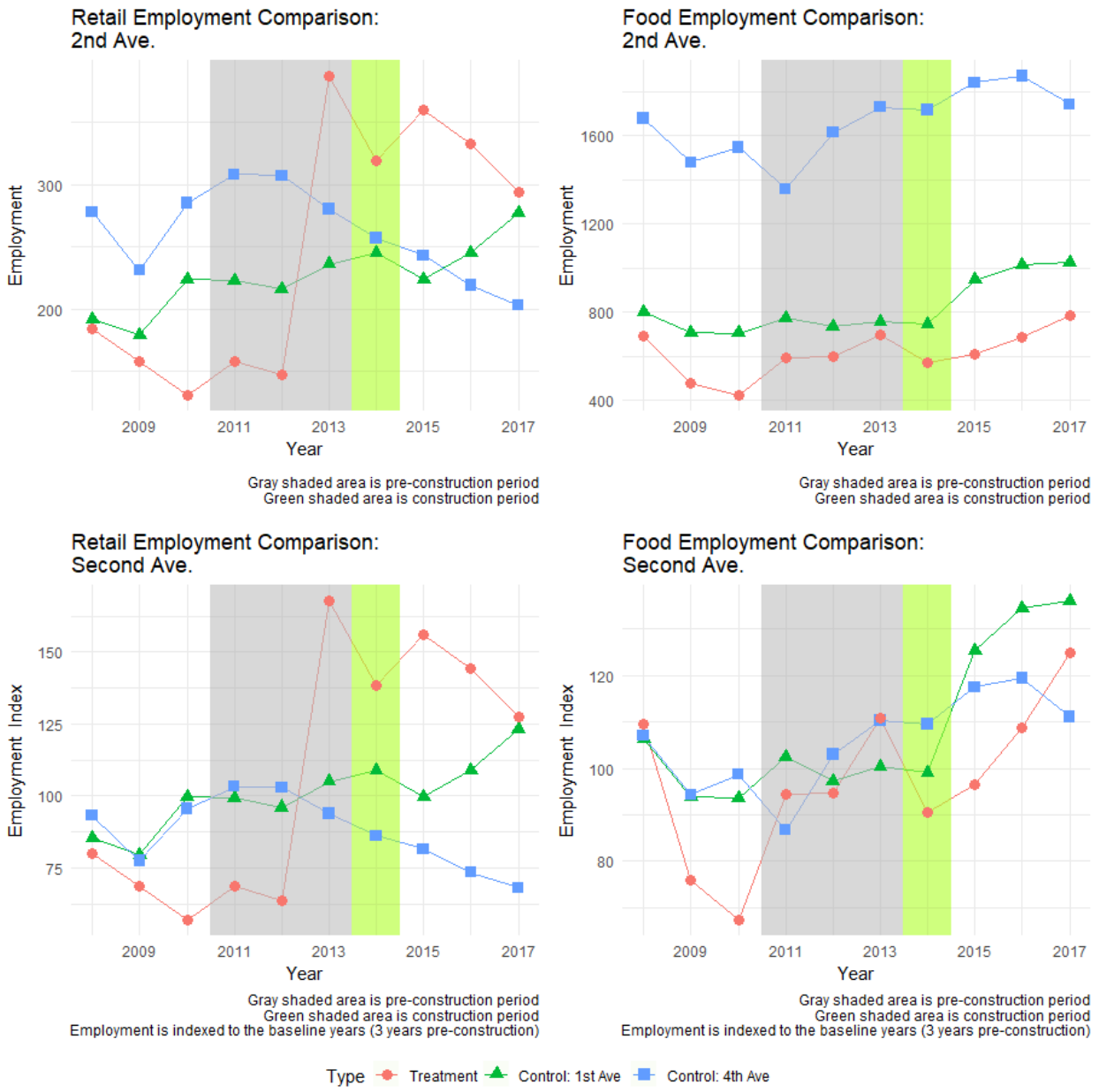


Figure 4-2. Second Avenue Employment Comparison (QCEW)

Table 4-1. Second Avenue Corridor Trend Analysis Summary Table

	Retail						Food					
	Baseline		Post-implementation				Baseline		Post-implementation			
Area	Base	Growth	1st Year	2nd Year	3rd Year	Avg.	Base	Growth	1st Year	2nd Year	3rd Year	Avg.
LEHD: [employment]												
Treatment	300	4.12%	14.33%	-	-	14.33%	991	-0.86%	0.20%	-	-	0.20%

Area	Retail						Food					
	Baseline		Post-implementation				Baseline		Post-implementation			
	Base	Growth	1st Year	2nd Year	3rd Year	Avg.	Base	Growth	1st Year	2nd Year	3rd Year	Avg.
Control: 4th Ave	399	-9.78%	-28.82%	-	-	-28.82%	1,436	16.79%	25.42%	-	-	25.42%
Control: 1st Ave	396	15.23%	34.60%	-	-	34.60%	1,227	2.74%	26.89%	-	-	26.89%
QCEW: [employment]												
Treatment	231	78.15%	55.84%	-7.50%	-11.71%	12.21%	628	8.57%	-3.34%	12.69%	14.62%	7.99%
Control: 4th Ave	298	-4.56%	-18.46%	-9.88%	-7.31%	-11.88%	1,566	12.95%	17.50%	1.63%	-6.90%	4.08%
Control: 1st Ave	225	3.06%	-0.44%	9.38%	13.06%	7.33%	753	-0.96%	25.37%	7.20%	1.19%	11.25

[1] Baseline is defined as the average of previous three years before construction year;
[2] Pre-growth rate is defined as average of baseline annual growth rate;
[3] 1st year growth rate is defined as the growth rate of the year after construction compared to baseline.

The table above summarizes the detailed percentage changes in retail and food services economic indicators across the LEHD and QCEW data. The LEHD employment data is only available one year after the street improvement on Second Avenue, therefore the LEHD trend post-treatment is less comprehensive and less reliable compared to the QCEW data, which shows three-year post-treatment trend. It shows the street improvement on Second Avenue positively impact retail employment, especially compared to the Fourth Avenue.

4.1.2 DID Analysis

DID analysis of LEHD data indicates the Second Avenue treatment corridor exhibits a statistically significant and negative effect of infrastructure construction on the number of food service employment, but non-significant effect on retail employment. However, as mentioned before, due to the limitation of data, there is only one year after installation time available, which brings about substantial caveats to infer long-term impact.

The QCEW DID results show some difference results then LEHD analysis. Most of the DID estimators indicates non-significant results, except prepost:control_4th Ave term, indicating a positive impact of street improvement on retail employment on Second Avenue corridor, comparing with Fourth Avenue corridor.

4.1.3 ITS Analysis

ITS analysis of the Second Avenue corridor using LEHD data does not show any significant level or slope change from the pre-treatment trend patterns. The level change and slope change estimators for all the models are statistically insignificant, which indicates the effect of treatment is not apparent. The Second Avenue treatment corridor does not exhibit a statistically significant effect of new bicycle infrastructure replacement.

The QCEW analysis show similar results as LEHD analysis. None of the key interested variables are statistically significant. While the ts_year coefficient for retail is positive and significant this only tells us that the growth trend of retail employment for the corridor is

itself positive. The non-significant **prepost** and **ts_year:pre_post** indicate that there was neither a level or slope change attributable to the treatment. It indicates that the protected bike lane did not statistically significantly impact employment, and the increasing employment in the retail and food sectors is likely the result of the continuous pattern of growth along Second Avenue.

4.1.4 Key Results

- The LEHD employment data is only available one year after the street improvement on Second Avenue, therefore the LEHD trend post-treatment is less comprehensive and less reliable compared to the QCEW data, which shows three-year post-treatment trend.
- Both the trend analysis and DID analysis show that the protected bike lane on Second Avenue corridor positively impacted employment, especially in the retail sector, when compared to the Fourth Avenue control corridor.
- However, the ITS analyses indicate that the protected bike lane did not statistically significantly impact employment, and the increasing employment in the retail and food sectors is likely the result of the continuous pattern of growth along Second Avenue.
- Given these results, we can conclude that the protected two-way bike lane contributed to higher employment and improved business vitality in the retail sector on the Second Avenue corridor, but cannot make the same conclusion for the food services sector.

4.2 Broadway Corridor

4.2.1 Aggregated Trend Analysis

4.2.1.1 LEHD

On Broadway Street corridor, retail employment trend is very similar for treatment corridor and 15th Ave East corridor before the construction of bike lane. However, the second control corridor, East Olive Way, remain relatively flat before 2013, which is unlike the improvement corridor. The growth trend of food service sector are almost parallel across three corridors.

The indexed plot suggest more detail changes of employment over years. The bike facility installation has taken place in 2013. The business employment continues to growth after two-year bike lane installation. However, it shows similar growth pattern with control corridors, if taking into the account of average of the two. There is a significant drop of retail employment after bike lane installation in Broadway Street corridor, but the control corridors generally continued to grow. Although retail employment recovered after one year, there is still caveats that bike lane might negatively affect retail services right after the construction period.

In terms of food employment, treatment corridor increased greatly after one-year bike lane installation. The two other corridor still maintains the similar trend as below. This indicates the potential positive effect of bike lane on food service employment.

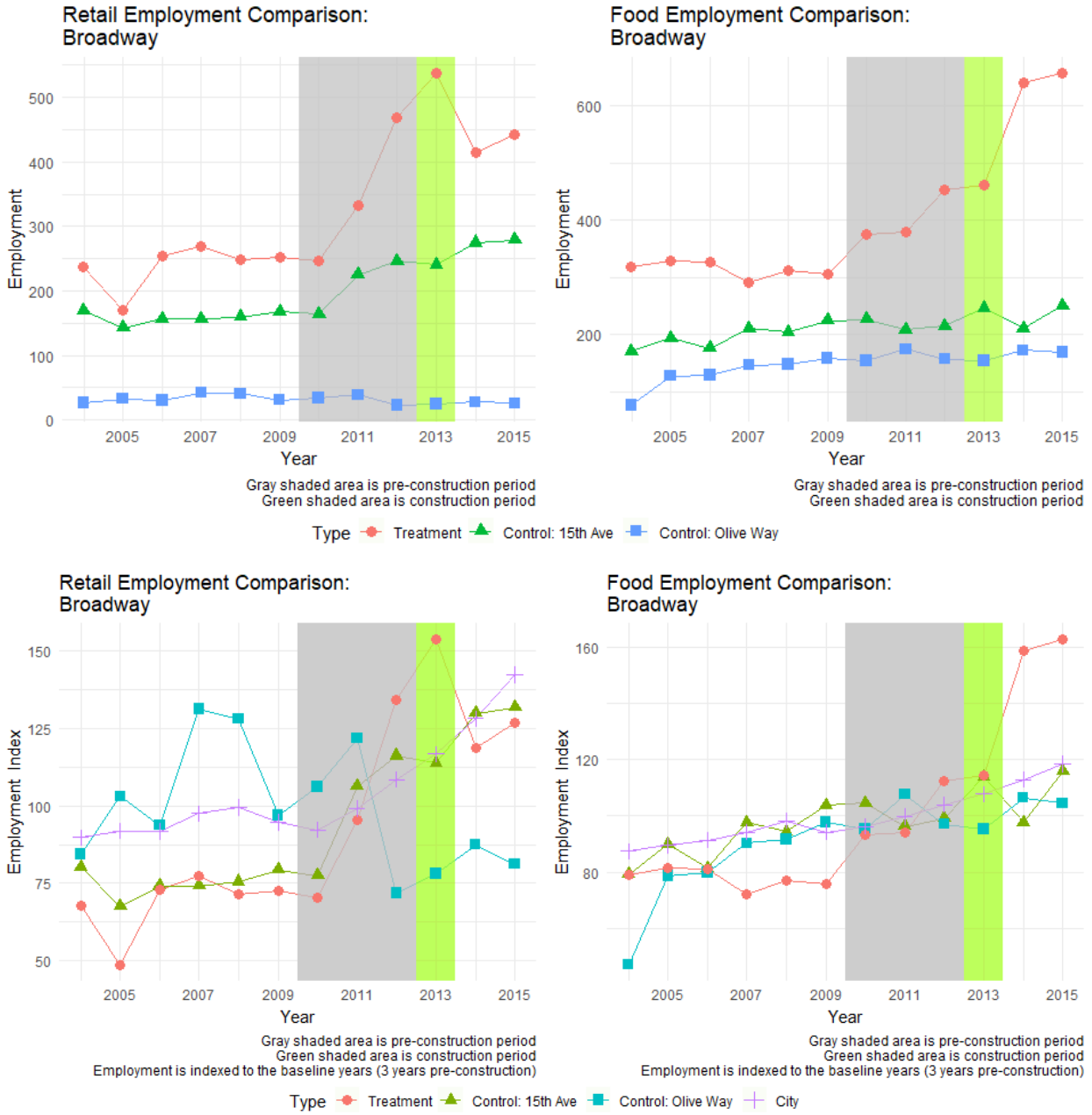


Figure 4-3. Broadway Corridor Employment Comparison (LEHD)

4.2.1.2 QCEW Data

Given more recent years data points available in QCEW data, the employment trends are much clearer than LEHD data. Both retail and food employment increase greatly after street improvement, comparing both control corridors. In particular, the food employment

growth rate in Broadway Street corridor exceeds both control corridors significant, indication a positive impact of street improvement on food employment.

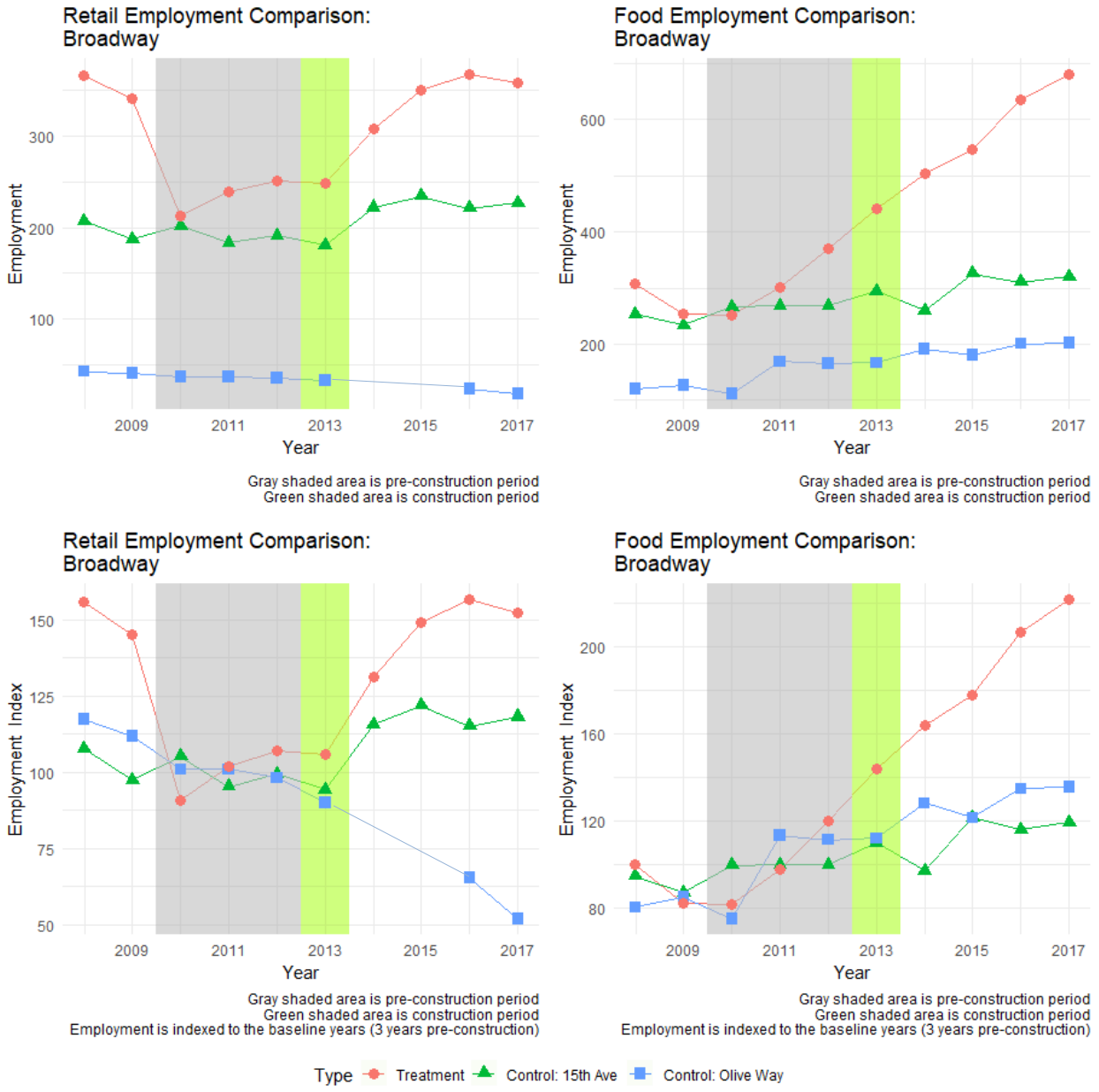


Figure 4-4. Broadway Corridor Employment Comparison (QCEW)

Table 4-2. Broadway Corridor Trend Analysis Summary Table

	Retail						Food					
	Baseline		Post-implementation				Baseline		Post-implementation			
Area	Base	Growth	1st Year	2nd Year	3rd Year	Avg.	Base	Growth	1st Year	2nd Year	3rd Year	Avg.
LEHD: [employment]												

Area	Retail						Food					
	Baseline		Post-implementation				Baseline		Post-implementation			
	Base	Growth	1st Year	2nd Year	3rd Year	Avg.	Base	Growth	1st Year	2nd Year	3rd Year	Avg.
Treatment	349	37.95%	18.91%	6.75%	-	12.83%	403	10.27%	59.06%	2.50%	-	30.78%
Control: Olive Way	32	-13.16%	-12.50%	-7.14%	-	-9.82%	162	1.61%	6.17%	-1.74%	-	2.49%
Control: 15th Ave	212	23.26%	29.72%	1.45%	-	15.59%	216	-2.54%	-2.31%	18.48%	-	16.17%
QCEW: [employment]												
Treatment	234	8.61%	31.62%	13.31%	5.16%	16.70%	308	21.18%	63.64%	8.53%	16.09%	29.42%
Control: Olive Way	37	-1.35%	-	-	-	-	149	24.56%	28.19%	-5.24%	11.05%	11.33%
Control: 15th Ave	192	-2.52%	15.62%	5.41%	-5.56%	5.16%	268	0.19%	-2.99%	25.38%	-4.60%	5.93%

[1] Baseline is defined as the average of previous three years before construction year;
[2] Pre-growth rate is defined as average of baseline annual growth rate;
[3] 1st year growth rate is defined as the growth rate of the year after construction compared to baseline.

The table above summarizes the detailed percentage changes in retail and food services economic indicators across LEHD and QCEW data. LEHD data shows that retail employment growth slows down after street improvement, but remains positive; while QCEW data indicates greater retail employment growth rates after street improvement. LEHD data shows that retail employment growth slows down after street improvement, but remains positive; while QCEW data indicates greater retail employment growth rates after street improvement.

4.2.2 DID Analysis

In terms of LEHD analysis, although the trend graph shows negative effect of bike lane installation on retail employment, the DID estimators for retail employment is not statistically significant, which indicates the effect of treatment is not apparent. On the other hand, treatment corridor exhibits a statistically significant and positive effect of infrastructure construction on the number of food service employment.

Additionally, DID analysis of QCEW data indicates Broadway Street improvement exhibits a statistically significant and positive effect on the number of both retail and food service jobs. According to our model, Broadway Street grew by more than around 80 retail jobs and over 200 food service jobs in total compared to the control corridor.

4.2.3 ITS Analysis

ITS analysis of the Broadway Street corridor using LEHD data does not show any significant level or slope change from the pre-treatment trend patterns. While the ts_year coefficient for retail is positive and significant this only tells us that the growth trend of retail employment for the corridor is itself positive. The non-significant **prepost** and **ts_year:pre_post** indicate that there was neither a level or slope change attributable to the treatment.

The QCEW ITS estimates shows a positive and significant change in the slope of retail employment. This follows from the visual inspection of employment that shows a clear jump after street improvement, indicating a positive effect of street improvement on retail employment.

4.2.4 Key results

- LEHD data shows that retail employment growth slows down after street improvement, but remains positive; while QCEW data indicates greater retail employment growth rates after street improvement.
- Both data sources indicate food services employment increased considerably after street improvement on Roosevelt Way, compared to the two control corridors.
- DID models show a positive causal effect of bike lane installation for food services employment on Broadway when compared to the two control corridors, and significant positive effect on retail employment when compared to the Olive Way control corridor.
- However, ITS analyses indicate there are no statistically significant impact of the protected bike lane on employment, and the increasing retail and food services employment is likely the result of the continuous pattern of growth along Broadway.
- In conclusion, the protected bike lane on Broadway triggered a significant employment increase in the food services industry after installation, indicating an improvement in business vitality as a result.

5. Conclusion & Limitation

Based on our analysis of the two street improvement corridors in Indianapolis, we found street improvement projects either improve, or had insignificant impacts on, economic outcomes. In particular, we can conclude that:

- On the Second Avenue corridor, the protected two-way bike lane contributed to higher employment and improved business vitality in the retail sector.
- On Broadway Avenue, we find that the protected bike lane triggered a significant positive impact on food services employment after installation, indicating an improvement in business vitality as a result.

In terms of retail service sector, we found either mixed results or insignificant results. This is typically due to either insufficient number of data points before or after the completion of the street improvement (for ITS analysis), or control corridors that may not be fully comparable (for DID analysis). However, the insignificant results may be significant in this context, indicating that there does not appear to be a negative causal impact of right-of-way or parking lane removal on economic outcomes.

Two data sources were used for this analysis, each with its pros and cons. The analysis results using the three data sources should be viewed as complementary to each other. LEHD data is comprehensive, easy to access, and provides rough trends of employment change at small geographical scales. It allows for comparisons between the street improvement corridors with overall city economic trends, and for both treatment and control corridor selection without obtaining additional data. Once street improvement corridor selection is completed, sales tax data (sales revenue) and QCEW data (employment and wages) can provide finer grain economic activity details. In Indianapolis, sales tax data may only capture parts of economic activities that are subject to sales tax, because sales of unprepared food and healthcare are tax exempt; and aggregated QCEW data for Indianapolis only identifies the food and drinking places sector (excluding retail service industries).

We employed three different analytical approaches to investigate the economic impacts of street improvement corridors. Aggregated trend analysis and difference-in-difference (DID) analysis both utilize control corridors to determine the impacts of the street improvement corridor, while the interrupted time series (ITS) analysis uses multiple time points on the street improvement corridor itself to pinpoint economic outcomes. In general, the ITS analysis provides more robust results than the other two methods, since it is less likely to be affected by the selection of control corridors. However, this method generally requires more data points post-intervention to achieve meaningful and valid impact estimations. The DID approach is heavily dependent on finding comparable control corridors (which may not always exist), so the analytical results may be weakened when appropriate corridors cannot be identified.

Additional data points after the completion of street improvements may help to provide further validity and rigor to the analysis of resulting economic outcomes. Moreover, further contextual information about the street improvement corridor, such as quality or level of the improvement, number of parking spot reduction, and subsequent bicycle ridership or

pedestrian increases, would help to better understand the linkages between the improvements and potential economic impacts. Extending this research to more closely examine the changes and shifts in industrial patterns will be valuable as well.

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7. Technical Appendix

The following section presents the corridor comparison result, estimation tables of the difference-in-difference (DID) and interrupted time series (ITS) analysis for each corridor group. The sections are organized by the data source of the model: LEHD, sales tax and QCEW. Please refer to the appropriate sections earlier in the report for descriptions of the data, methodology and interpretation of the results.

Table. T-statistics of Corridor Comparison T-test (numbers in parentheses is p-value)

Corridor	Job per block		Business job share		Pre-construction growth rate	
	Retail	Food	Metric 1	Metric 2	Retail	Food
Second Avenue						
First	-1.090 (0.282)	-0.906 (0.37)	-2.064 (0.046)	-1.651 (0.107)	0.959 (0.352)	-1.138 (0.271)
Fourth	-0.208 (0.835)	-0.998 (0.324)	-1.048 (0.300)	0.823 (0.415)	2.058 (0.05)	-0.546 (0.592)
Broadway						
15th Avenue	-0.882 (0.397)	-1.179 (0.255)	-3.847 (0.001)	-4.439 (0.000)	0.061 (0.858)	-0.105 (0.643)
Olive	1.793 (0.083)	0.591 (0.558)	-2.349 (0.029)	-1.194 (0.245)	0.017 (0.975)	-0.063 (0.724)
Roosevelt						
University	-0.392 (0.697)	-2.854 (0.008)	-1.288 (0.205)	-0.670 (0.506)	-0.025 (0.909)	0.005 (0.996)
45th Street	1.599 (0.116)	-0.874 (0.385)	-1.084 (0.282)	-0.900 (0.371)	0.007 (0.991)	-0.028 (0.895)

LHED data

Second Avenue Corridor Difference-in-Difference Estimates

	Dependent variable:		
	CNS07	CNS18	business
	Retail Emp.	Accomodations Emp.	'Business' Emp.
	(1)	(2)	(3)
TypeControl: 1st Ave	123.545***	-27.182	96.364
	(43.423)	(70.636)	(85.647)
TypeControl: 4th Ave	284.273***	435.636***	719.909***
	(43.423)	(70.636)	(85.647)
prepost	95.545	-96.636	-1.091
	(106.365)	(173.022)	(209.792)
TypeControl: 1st Ave:prepost	66.455	591.182**	657.636**
	(150.422)	(244.690)	(296.690)
TypeControl: 4th Ave:prepost	-343.273**	372.364	29.091
	(150.422)	(244.690)	(296.690)
Constant	247.455***	1,089.636***	1,337.091***
	(30.705)	(49.947)	(60.562)
Observations	36	36	36
R^2	0.607	0.705	0.762
Adjusted R^2	0.542	0.656	0.723
Residual Std. Error (df = 30)	101.836	165.656	200.860
F Statistic (df = 5; 30)	9.274***	14.329***	19.230***
Note:			*p<0.1;* ***p<0.05;*** p<0.01

Second Avenue Corridor Interrupted Time Series Estimates

	Dependent variable:		
	CNS07	CNS18	business
	Retail Emp.	Accomodations Emp.	'Business' Emp.
	(1)	(2)	(3)
ts_year	17.055***	-20.964*	-3.909
	(2.727)	(11.327)	(12.920)
prepost	-6.782	29.145	22.364
	(34.061)	(141.471)	(161.376)
ts_year:prepost			
Constant	145.127***	1,215.418***	1,360.545***
	(18.496)	(76.822)	(87.631)
Observations	12	12	12
R^2	0.846	0.309	0.010
Adjusted R^2	0.811	0.156	-0.210
Residual Std. Error (df = 9)	28.601	118.796	135.511
F Statistic (df = 2; 9)	24.670***	2.016	0.046
Note:			*p<0.1;* ***p<0.05;*** p<0.01

Broadway Corridor Difference-in-Difference Estimates

	Dependent variable:		
	CNS07	CNS18	business
	Retail Emp.	Accomodations Emp.	'Business' Emp.
	(1)	(2)	(3)
TypeControl: 15th Ave E	-118.600***	-147.900***	-266.500***
	(29.574)	(17.482)	(44.482)
TypeControl: E Olive Way	-269.200***	-213.000***	-482.200***
	(29.574)	(17.482)	(44.482)
prepost	127.300**	293.700***	421.000***
	(51.223)	(30.280)	(77.045)
TypeControl: 15th Ave E:prepost	-33.400	-270.600***	-304.000***
	(72.441)	(42.822)	(108.957)
TypeControl: E Olive Way:prepost	-132.800*	-265.500***	-398.300***
	(72.441)	(42.822)	(108.957)
Constant	301.700***	355.300***	657.000***
	(20.912)	(12.362)	(31.453)
Observations	36	36	36
R^2	0.809	0.926	0.878
Adjusted R^2	0.777	0.914	0.858
Residual Std. Error (df = 30)	66.129	39.091	99.464
F Statistic (df = 5; 30)	25.369***	75.413***	43.251***
Note:			*p<0.1;* ***p<0.05;*** p<0.01

Broadway Corridor Interrupted Time Series Estimates

	Dependent variable:		
	CNS07	CNS18	business
	Retail Emp.	Accomodations Emp.	'Business' Emp.
	(1)	(2)	(3)
ts_year	30.988***	16.285***	47.273***
	(7.572)	(4.230)	(10.792)
prepost	-24.267	199.267	175.000
	(1,120.614)	(625.947)	(1,597.086)
ts_year:prepost	-2.988	-0.285	-3.273
	(97.561)	(54.495)	(139.043)
Constant	131.267**	265.733***	397.000***
	(46.984)	(26.244)	(66.962)
Observations	12	12	12
R^2	0.738	0.934	0.862
Adjusted R^2	0.640	0.909	0.810
Residual Std. Error (df = 8)	68.778	38.418	98.022
F Statistic (df = 3; 8)	7.513**	37.439***	16.678***
Note:			*p<0.1;* ***p<0.05;*** p<0.01

QCEW data

Second Avenue Corridor Difference-in-Difference Estimates

	Dependent variable:		
	CNS07	CNS18	business
	Retail Emp.	Accomodations Emp.	'Business' Emp.
	(1)	(2)	(3)
TypeControl: 1st Ave	4.429	167.714***	172.143**
	(29.207)	(49.734)	(62.978)
TypeControl: 4th Ave	66.000**	1,010.286***	1,076.286***
	(29.207)	(49.734)	(62.978)
prepost	117.000***	114.238*	231.238***
	(37.706)	(64.206)	(81.304)
TypeControl: 1st Ave:prepost	-84.762	133.952	49.190
	(53.324)	(90.801)	(114.982)
TypeControl: 4th Ave:prepost	-173.333***	115.048	-58.286
	(53.324)	(90.801)	(114.982)
Constant	212.000***	577.429***	789.429***
	(20.652)	(35.167)	(44.532)
Observations	30	30	30
R^2	0.379	0.968	0.953
Adjusted R^2	0.250	0.962	0.943
Residual Std. Error (df = 24)	54.641	93.044	117.821
F Statistic (df = 5; 24)	2.934**	147.499***	96.926***
Note:			*p<0.1;* ***p<0.05;*** p<0.01

Second Avenue Corridor Interrupted Time Series Estimates

	Dependent variable:		
	CNS07	CNS18	business
	Retail Emp.	Accomodations Emp.	'Business' Emp.
	(1)	(2)	(3)
ts_year	31.393*	8.821	40.214
	(13.781)	(18.744)	(28.904)
prepost	797.143	-965.690	-168.548
	(681.194)	(926.504)	(1,428.719)
ts_year:prepost	-64.393	79.679	15.286
	(53.373)	(72.594)	(111.944)
Constant	-39.143	506.857**	467.714*
	(113.641)	(154.565)	(238.347)
Observations	10	10	10
R^2	0.647	0.434	0.538
Adjusted R^2	0.471	0.151	0.308
Residual Std. Error (df = 6)	72.922	99.182	152.945
F Statistic (df = 3; 6)	3.668*	1.533	2.333
Note:			*p<0.1;* ***p<0.05;*** p<0.01

Broadway Corridor Difference-in-Difference Estimates

	Dependent variable:		
	CNS07 Retail Emp.	CNS18 Accomodations Emp.	business 'Business' Emp.
	(1)	(2)	(3)
TypeControl: 15th Ave	-84.167***	-56.667*	-140.833***
	(18.054)	(27.658)	(33.872)
TypeControl: Olive Way	-238.167***	-177.500***	-415.667***
	(18.054)	(27.658)	(33.872)
prepost	69.250***	270.750***	340.000***
	(20.185)	(30.922)	(37.870)
TypeControl: 15th Ave:prepost	-35.083	-230.833***	-265.917***
	(28.546)	(43.731)	(53.556)
TypeControl: Olive Way:prepost	-85.583**	-220.500***	-298.333***
	(32.548)	(43.731)	(61.064)
Constant	276.000***	321.000***	597.000***
	(12.766)	(19.557)	(23.951)
Observations	28	30	28
R^2	0.941	0.908	0.955
Adjusted R^2	0.927	0.888	0.944
Residual Std. Error	31.271 (df = 22)	47.905 (df = 24)	58.668 (df = 22)
F Statistic	69.875*** (df = 5; 22)	47.108*** (df = 5; 24)	92.709*** (df = 5; 22)
Note:			*p<0.1;* ***p<0.05;*** p<0.01

Broadway Corridor Interrupted Time Series Estimates

	Dependent variable:		
	CNS07 Retail Emp.	CNS18 Accomodations Emp.	business 'Business' Emp.
	(1)	(2)	(3)
ts_year	-23.600**	30.571**	6.971
	(9.596)	(10.245)	(18.475)
prepost	-314.000	-273.714	-587.714
	(237.084)	(253.121)	(456.451)
ts_year:prepost	40.100*	31.329	71.429
	(20.356)	(21.733)	(39.191)
Constant	453.000***	91.714	544.714***
	(73.812)	(78.805)	(142.108)
Observations	10	10	10
R^2	0.701	0.950	0.896
Adjusted R^2	0.551	0.926	0.844
Residual Std. Error (df = 6)	40.143	42.858	77.286
F Statistic (df = 3; 6)	4.678*	38.372***	17.245***
Note:			*p<0.1;* ***p<0.05;*** p<0.01