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The Effect of Bike Share Expansion on Bay Area Rapid Transit Ridership

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THE EFFECT OF BIKE SHARE EXPANSION ON BAY AREA RAPID TRANSIT RIDERSHIP

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ABSTRACT

JACOB HOLIFIELD: The Effect of Bike Share Expansion on Bay Area Rapid Transit Ridership
(Under the direction of Dr. Thomas Garrett)

The transportation sector causes significant negative externalities (collisions and pollution), most of which are caused by cars. As a result, policymakers often seek to reduce reliance on cars and spur demand for alternative modes of transportation. Many urban planners posit that bike sharing could serve to increase public transit ridership by allowing the bike sharing system to feed into the public transit stations, thereby solving first- and last-mile problems and reducing the time cost to access public transit. However, research into the effect of bike sharing on public transit is mixed. This thesis examines the effect of the 2017 expansion of the bike sharing system in the San Francisco Bay Area on Bay Area Rapid Transit (BART) ridership. The empirical results reveal that bike share expansion reduced BART ridership on average, with a relatively large reduction to weekend BART ridership and no effect on those BART stations in low-density neighborhoods. These results indicate that, while bike sharing might be solving first- and last-mile problems for some individuals in the Bay Area, the expansion reduced BART ridership on average, and that the relationship between bike sharing and public transit may be substantially different depending on the purpose of the trip (leisure or work) and the urban density of the surrounding area.

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Section I: Introduction

A developed and growing economy would not exist without the ability to exchange goods or move people via transportation systems such as roads, rail, etc. However, transportation generates significant negative externalities, such as air pollution and collisions. In 2020, the transportation sector[1] was the largest source of greenhouse gas emissions in the United States at 27 percent of total emissions, and emissions from the transportation sector have increased more in absolute terms than that of any other sector.[2] Furthermore, in 2019 traffic collisions accounted for $340 billion in damages and resulted in over 36,000 deaths.[3] Most of these negative externalities are due to cars, whereas other modes of transportation are associated with relatively fewer negative externalities. In particular, rail transportation causes far fewer collisions, and both rail and bicycling emit far smaller amounts of greenhouse gases per passenger mile. Because of this, policymakers often seek ways of increasing demand for public transit and bicycling, and many posit that multi-modal transportation systems might further this goal. However, the relationship between cycling and public transportation (such as rail) is not well understood. Because of the importance of transportation to the economy and the significance of transportation externalities, research into this relationship is needed to better inform and guide urban policy.

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[1] Transportation sector emissions originate from highway vehicles, aircraft, ships and boats, rail, lubricants, and pipelines. Pipeline emissions include only the emissions created from the compressors that power the pipeline.

[2] https://www.epa.gov/transportation-air-pollution-and-climate-change/carbon-pollution-transportation#transportation

[3] https://www.nhtsa.gov/press-releases/traffic-crashes-cost-america-billions-2019

Rail has been an indispensable mode of transportation in the United States since 1827 when the first U.S. railroad was chartered[4]. Today, there are roughly 140,000 route miles of freight rail[5], and nearly every major city has access to some form of passenger rail. Rail is far less prone to negative externalities, such as pollution, than transportation via automobile. When compared to National Rail in the United Kingdom, a medium-sized gasoline-powered car emits nearly five times more greenhouse gases per passenger mile[6]. Furthermore, Boarnet et al. (2017) find that new light rail stations in Los Angeles reduce greenhouse gas emissions of the households in their vicinity by causing substitution from cars to light rail. However, there are also less obvious ways in which rail and automobiles differ. For example, passenger rail carries significantly less risk of fatality than does automobile travel. Savage (2013) finds that fatality risk per passenger mile is 17 times higher for car travel than for commuter rail travel, 30 times higher than for urban mass-transit rail, and that highway crashes account for 95 percent of U.S. transportation fatalities from 2000 to 2009.

The rise of technology has contributed greatly to the rise of the “sharing economy”, which spawned Uber, Airbnb, and the many bike sharing programs across the globe. Bike sharing programs allow users to rent bicycles on an as-needed basis by using their smartphones. The first bike share program emerged in Amsterdam in 1965[7], and the first modern bike sharing programs in the United States appeared in 2010[8]. Despite the relatively short amount of time since its appearance, bike sharing has seen explosive

[4] https://www.aar.org/chronology-of-americas-freight-railroads/
[5] https://railroads.dot.gov/rail-network-development/freight-rail-overview
[6] https://ourworldindata.org/travel-carbon-footprint
[7] https://www.theguardian.com/cities/2016/apr/26/story-cities-amsterdam-bike-share-scheme
[8] https://nacto.org/bike-share-statistics-2016/

growth. Some of this growth can be attributed to the fact that most trips cover no more than three miles, rendering bicycles a viable alternative to cars for many commuters.[9] In 2010, U.S. bike share programs had only 1,600 bikes which generated 320 thousand trips; however, by the end of 2016, these numbers rose to 42 thousand and 28 million respectively. In the wake of this rapid expansion, much research has been conducted to understand the costs and benefits of bike sharing programs.

Benefits commonly attributed to bike sharing programs include reducing vehicle emissions, health benefits from increased physical activity, and reductions in congestion. Basu and Farreira (2021) find via a spatial difference-in-differences model that bike share reduced vehicle ownership, vehicle miles driven, and greenhouse gas emissions per household in Boston. Furthermore, Wang and Zhou (2017) find that bike share reduces congestion. Another claimed benefit of bike sharing is that bike sharing programs increase public transit ridership by solving first- and last-mile problems. For example, if someone wishes to take the metro, but the metro station is not within comfortable walking distance, this person has a first-mile problem: their commute to the metro station is costly. Conversely, if someone departs the metro, but the destination is not within comfortable walking distance of the metro station, this person has a last-mile problem: the commute from the metro station to the destination has a significant time cost. If a given city installs bike sharing stations at major destinations, public transit stations, and residential areas, then the area which those public transit stations can effectively serve increases.

Despite the seemingly clear way in which bike sharing could increase public transportation ridership, the way bike share programs integrate with public transit in

[9] https://www.energy.gov/eere/vehicles/articles/fotw-1230-march-21-2022-more-half-all-daily-trips-were-less-three-miles-2021

reality is not so simple. Bike sharing might impact public transportation ridership in three ways; namely, they could be substitute, complement, or unrelated goods. If bike sharing is a complement for public transit, then the presence of a bike sharing station in the vicinity of a public transit station would increase public transit ridership. However, if bike sharing is a substitute for public transit, then a person might decide to switch from public transit to bike share for their daily commute. If they are unrelated, then the bike sharing station would have no impact on public transit ridership.

Research into the relationship between public transit and bike sharing is mixed. In New York City, bike sharing along bus routes has been shown to decrease bus ridership (Campbell and Brakewood 2017), suggesting some degree of substitution between bike sharing and the bus system in New York City. However, it has also been shown in Boston that bike sharing stations near public transit stations provide larger reductions to automobile dependence than those located further away from public transit stations (Basu and Ferreira 2021). This suggests that these bike sharing stations are solving first- and last-mile problems, thus indicating complementarity.

The mixed results of the research into the relationship between public transit and bike sharing warrant further study. This thesis examines the effect of the 2017 expansion of the bike sharing system in the San Francisco Bay Area on Bay Area Rapid Transit (BART) ridership at 48 stations. Monthly data from the Bay Wheels bike sharing program and Bay Area Rapid Transit from the years 2015 to 2020 are used (excluding those months in 2020 impacted by COVID-19). I construct a panel dataset in which a binary treatment variable is equal to one for those observations in which a Bay Area Rapid Transit station is within one quarter mile of a bike sharing station. Monthly average weekday ridership and monthly average weekend ridership variables are regressed on the treatment variable to determine any difference in weekday and weekend ridership before and after the expansion of the bike sharing program. I also separate BART stations into two subgroups (dense neighborhood and less-dense neighborhood) to examine the effect of urban form on the relationship between BART and the expansion of the bike share program.

The thesis proceeds as follows. Section II discusses the background of the Bay Area Rapid Transit system, the bike sharing program in the San Francisco Bay Area, and the conceptual framework for the empirical analysis. Section III details the data sources and empirical methodology. Section IV presents the results of the empirical analysis, and section V concludes with a review of the material discussed and provides directions for future research.

Section II: Background and Conceptual Framework

Before presenting the analysis, it is important to first understand the background of BART, the bike sharing program in the Bay Area, and the conceptual framework that serves as the basis for the empirical analysis. This section provides a brief overview of these transportation systems and outlines the ways in which bike sharing might impact an individual's transportation mode choice in the Bay Area.

Background on BART and Bike Sharing in the Bay Area

BART is a rapid transit system operating in the San Francisco Bay Area. Rapid transit, also known as heavy rail or metro, is differentiated from light rail in that rapid transit is wholly separate from other modes of transportation and thus maintains right-of-way at all times. Rapid transit is also faster and has a higher passenger capacity than light rail. Other examples of rapid transit include the New York City Subway system, the Chicago "L", the Washington D.C. Metro system, and the Massachusetts Bay Transportation Authority Subway in Boston.

The idea for BART began in 1946 as post-war immigration to the Bay Area led to an increase in automobile traffic and congestion.[10] Informal chatter of an electric train linking Oakland and San Francisco was spurred by this increase in congestion and the expectation that it would get worse in the future. To meet the demand for public transportation, the Bay Area Rapid Transit Commission was formed in 1951 to study the transportation needs of the Bay Area. In 1957, the San Francisco Bay Area Rapid Transit

[10] https://www.bart.gov/about/history

District was formed, and construction began in 1964.[11] BART officially opened for revenue service on September 11, 1972.[12] In its first year of service, BART carried roughly nine million passengers.[13] BART opened with 28 miles of track and 12 stations, but by 1991, BART had expanded to 104.5 miles with 44 stations.[14] By 2018, ridership had grown to 126 million annually. Today, BART operates on 131 miles of track and 50 stations.[15]

Bike sharing in the San Francisco Bay Area began as Bay Area Bike Share as part of the Metropolitan Transportation Commission's Climate Initiatives Program. Bay Area Bike Share's goal was to increase public transit ridership and reduce air pollution by decreasing reliance on cars. The program officially started operation in August of 2013 and consisted of 70 bike sharing stations with 700 bicycles in San Francisco, San Jose, Palo Alto, Mountain View, and Redwood City.[16] One could purchase a daily pass for $9 or an annual pass for $88, where either pass allowed for unlimited 30-minute rides until expiration.

The bike sharing program underwent a large expansion in 2017, funded by a sponsorship from Ford Motor Company.[17] Bay Area Bike Share was rebranded as Ford GoBike, and by January of 2018, the bike sharing system had expanded to include 262 stations with 2,600 bicycles.[18] This expansion also introduced bike sharing to the East Bay, which includes Oakland and Berkeley. In 2019, Motivate, the company that operates the

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[11] https://www.bart.gov/about/history/history2
[12] https://www.bart.gov/about/history/history3
[13] https://www.bart.gov/sites/default/files/docs/June18FactSheet_v1.pdf
[14] https://www.bart.gov/sites/default/files/docs/bart-historical-timeline.pdf
[15] https://www.bart.gov/about
[16] https://mtc.ca.gov/news/bay-area-bike-share-pilot-program-launch-august-29-2013
[17] https://techcrunch.com/2017/06/27/ford-gobike-launches-in-the-bay-area-starting-tomorrow/
[18] https://web.archive.org/web/20180617015310/https://www.fordgobike.com/blog/ford-gobike-passes-growth-milestones

bike sharing programs in the San Francisco Bay Area, New York City, Chicago, Portland, Boston, and Columbus was acquired by the ridesharing company Lyft. After this acquisition, Ford GoBike was renamed Bay Wheels.[19] Today, the Bay Wheels system includes 550 bike sharing stations and 7,000 bicycles,[20] and prices include a per-trip rental rate of $3.49, an annual membership rate of $169, and a monthly membership rate of $29.[21] Members have unlimited trips under forty-five minutes until expiration of the membership.

Conceptual Framework

Economic theory says that an individual will choose the least costly mode of transportation available to him or her in order to maximize his or her utility. The total cost of a trip for a given person and a given mode of transportation can be represented by the sum of the monetary cost, the disutility associated with the time it takes to access the given mode, and the disutility associated with the time spent in-vehicle in the given mode. The expansion of the bike sharing system has a number of possible effects on a person's mode choice in the Bay Area. The expansion of bike sharing might allow people who live further away from a BART station to access the BART system much faster than before. Thus, with respect to BART, the expansion of bike sharing might increase the monetary cost while reducing the access cost. However, bike sharing expansion also reduces the access costs associated with the bike sharing system itself, which might spur substitution from BART to the newly expanded bike sharing system.

[19] https://www.sfchronicle.com/business/article/Lyft-renames-bike-rentals-as-Bay-Wheels-13966479.php
[20] https://mtc.ca.gov/operations/traveler-services/bay-wheels-bike-share-program
[21] https://www.lyft.com/bikes/bay-wheels/pricing

While it is important to consider how these modes of transportation might interact with each other, it is also important to consider how different individuals might have different disutility costs. For example, Martin and Shaheen (2014) argue that bike sharing is more likely to act as a complement for public transit for individuals living in neighborhoods that are less densely populated. In absolute terms, the reduction in access cost to public transit might be relatively higher for individuals living in low-density neighborhoods compared to individuals living in high-density neighborhoods. Furthermore, those living in low-density neighborhoods might be less likely to see a significant reduction in access cost to the bike sharing network than those living in high-density neighborhoods.

Different types of trips might impose different sets of costs. For example, it could be the case that commutes to work impose different disutility than commutes for leisure purposes (such as commutes to public parks, restaurants, etc.). In this case, it might be the case that leisure trips are relatively less costly on bicycles than work-related trips, as a person might enjoy their time on bicycles relatively more when they are commuting for leisure rather than work. If this is the case, it might be that leisure trips impose relatively more substitution between bike sharing and BART than do work trips. Furthermore, there could be indirect effects to public transit from bike sharing expansion. Campbell and Brakewood (2017) posit that a substitution away from buses and toward bike sharing might encourage new riders to take the bus due to a reduction in the number of bus passengers, or that the opening of a bike share program might make people more likely to ride private bicycles due to the perception that the area is more bicycle-friendly than before. If these private bicyclists were previously riding the bus, bike sharing would indirectly reduce bus ridership.

For different individuals, any of these scenarios could be happening at any time. Some people may choose to ride BART more often, some people who did not previously use BART might choose to start using it, and some people who were previously frequent users of BART might choose to use the bike sharing system instead. Thus, bike share expansion may cause either an increase or decrease in BART ridership. The empirical work that follows will provide additional insights into the overall effect of bike share expansion on BART ridership on commutes for work and leisure, as well as the potential effects of bike share expansion on BART stations in low- and high-density neighborhoods.

Section III: Data and Empirical Methodology

This section presents the data and empirical methodology used to examine the impact of the 2017 expansion of the bike sharing program in the Bay Area on BART ridership. The analysis is conducted using a panel dataset with monthly BART ridership data, Bay Wheels bike-sharing data, and the walkability index from Walk Score®. The analysis includes monthly data from February 2015 to February 2020 for 48 BART stations.

The BART ridership data were acquired from BART's public ridership reports.[22] The Monthly Ridership Reports include average monthly entries and exits for a weekday, Saturday, and Sunday. I sum the average entries and exits for each observation, and I also sum the Saturday and Sunday averages for entries and exits and divide by two to create a single weekend average.

The bike share data were acquired from Bay Wheels System Data.[23] While there existed a small bike share program in the Bay Area beginning in August 2013, the data in this thesis only extend back to July 2017, which is when the bike sharing system was expanded due to the sponsorship from Ford Motor Company. The key variable is a treatment variable that is equal to one for those observations for which there is a bike-sharing station within one-quarter mile of a BART station and equal to zero otherwise. One-quarter mile is used because this is the distance that transit planners believe people are willing to walk to reach a bus stop.[24]

Walk Score® is a company that generates an automated index of walkability for a given location. The score ranges from zero to 100, where a higher score indicates a more

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[22] https://www.bart.gov/about/reports/ridership
[23] https://www.lyft.com/bikes/bay-wheels/system-data
[24] Campbell and Brakewood (2017)

walkable and dense area. I use Walk Score® to generate a walkability index for each BART station, which is a proxy for density.[25] While population density might seem the obvious choice for this purpose, the Walk Score® index might better capture a given area's density with respect to transportation. Furthermore, the Walk Score® index has been used as a measure of walkability in other academic studies.[26] I separate the panel dataset into two groupings: a high density group, which includes only those observations corresponding to BART stations in neighborhoods with Walk Scores greater than or equal to 90, whereas the low density group is composed of those observations corresponding to BART stations located in neighborhoods with Walk Scores less than 90.[27]

Table 1 provides summary statistics for the panel dataset. Note that mean weekday ridership is much higher than mean weekend ridership in all cases (total, high density, and low density). Also note that mean ridership is lower in the low-density grouping when compared to the high-density grouping. The Bike Share Expansion variable is the treatment variable, and the mean for this variable in each grouping can be interpreted as the percentage of observations in the given sample that are considered treated.

[25] https://www.walkscore.com/

[26] Hall and Ram (2018)

[27] https://www.walkscore.com/methodology.shtml Note: I use ninety as a cutoff because this is the threshold Walk Score® uses for the most walkable category.

Table 1: Summary Statistics

Variable	Mean	Median	Standard Deviation	Min	Max	Number of Observations
Weekday Ridership	18118	12744	344	1835	94188	2819
Weekend Ridership	6691	4714	6541	554	55334	2819
Weekday (High Density)	30331	23704	25091	8512	94188	1037
Weekend (High Density)	10933	7271	8761	2019	55334	1037
Weekday (Low Density)	11011	10322	4854	1835	26386	1782
Weekend (Low Density)	4224	3511	2544	554	16403	1782
Bike Share Expansion	0.1834	N/A	0.3871	0	1	2819
Bike Share Expansion (High Density)	0.3934	N/A	0.4887	0	1	1037
Bike Share Expansion (Low Density	0.0612	N/A	0.2397	0	1	1782

Note: There are 17 BART stations in the high density group and 31 in the low density group. See text for the definition of high and low density.

To analyze the impact of the 2017 expansion of the bike-sharing system in the Bay Area, I estimate the following regressions:

$$Weekday_{i,t} = \alpha_0 + (\beta)Treatment_{i,t} + \sum_{i=1}^{N-1}(\varphi_i)\, Station_i + \sum_{t=1}^{M-1}(\tau_t)Time_t + \varepsilon_{i,t}$$

$$Weekend_{i,t} = \alpha_0 + (\delta)Treatment_{i,t} + \sum_{i=1}^{N-1}(\varphi_i)\, Station_i + \sum_{t=1}^{M-1}(\tau_t)Time_t + \varepsilon_{i,t}$$

where $Weekday_{i,t}$ is the average monthly weekday BART ridership and $Weekend_{i,t}$ is the average monthly weekend BART ridership. $Treatment_{i,t}$ is equal to one if a bike sharing station is within one-quarter mile of the BART station for a given observation. $Station_i$ and $Time_t$ are dummy variables which are equal to one for a given observation if the BART station $i \in [1, N]$ or time $t \in [1, M]$ corresponds to the dummy variable $Station_i$ or $Time_t$ respectively. The dummy variables control for unobserved variation across time and across stations that is not due to treatment. The regressions are also estimated using subsets of the full dataset separated by walkability (density).

The coefficients β and δ measure the average difference in the dependent variables due to the treatment of the BART stations. In this case, these coefficients measure the impact of bike share expansion on weekend and weekday monthly average BART ridership. These two coefficients will reveal the effect that the 2017 bike share expansion had on BART ridership. If β or δ are negative, it would indicate that the bike share expansion reduced BART ridership on average for either weekday or weekend trips, respectively. This may indicate that bike sharing is a substitute for BART. Similarly, if either of these coefficients are positive, it would indicate that the bike share expansion increased BART ridership on average for the respective dependent variables. This may indicate that bike sharing is a complement for BART, and that bike sharing in the Bay Area is solving the first- and last-mile problems.

Section IV: Results

This section presents the estimates from the regression models presented in the previous section. Table 2 displays results for the entire panel dataset, whereas Table 3 displays results for the subsamples of neighborhood density.

Table 2: Impact of Bike Share Expansion on BART Ridership

Variable	Dependent Variable: Weekday Ridership	Dependent Variable: Weekend Ridership
Constant	543 (1526)	7683*** (1683)
Bike Share Expansion	-424*** (88)	-1253*** (97)
Adjusted R^2	0.996	0.962
Number of Observations	2819	2819

Note: * denotes significance at 10%, ** denotes significance at 5%, and *** denotes significance at 1%. All regressions include time and station dummy variables. Standard errors are in parentheses.

The results shown in Table 2 reveal that the treatment effect of the expansion of the bike sharing system is negative and statistically significant for both weekends and weekdays. The estimates reveal average weekday ridership was 424 passengers lower and average weekend ridership 1253 passengers lower after bike share expansion, thus suggesting that, on average, people in the Bay Area are using bike share as a substitute for BART. The magnitude of this effect is relatively smaller for weekday BART ridership, representing roughly a two percent change from the overall weekday mean of 18,118. However, the treatment effect on weekend BART ridership is large, representing roughly a 19 percent change from the overall weekend mean of 6691. This may indicate that those commuting for leisure are relatively more likely to substitute bike sharing for BART. For example, it could be the case that people in San Francisco enjoy riding bicycles when commuting for leisure, which would reduce the disutility of in-vehicle time relative to work-related trips and make bicycling relatively more attractive. In either case, it is clear that the 2017 bike share expansion did not increase BART ridership. While the bike sharing expansion might have solved first- and last-mile problems for a number of individuals, the substitution away from BART dominated.

Table 3: Impact of Bike Share Expansion in High and Low Density Neighborhoods

Variable	**Dependent Var. Weekday Ridership (High Density)**	**Dependent Var. Weekend Ridership (High Density)**	**Dependent Var. Weekday Ridership (Low Density)**	**Dependent Var. Weekend Ridership (Low Density)**
Constant	10639*** (3480)	16367*** (4426)	2332*** (1514)	6409*** (1227)
Bike Share Expansion	-548*** (199)	-1288*** (254)	78 (131)	-162 (106)
Adjusted R^2	0.996	0.961	0.972	0.920
Number of Observations	1037	1037	1782	1782

Note: * denotes significance at 10%, ** denotes significance at 5%, and *** denotes significance at 1%. Time and station dummy variable coefficients are omitted. Standard errors are given in parentheses.

Table 3 reveals that the effect of bike share expansion on those BART stations in high-density neighborhoods is similar to the effect of bike share expansion on the Bay Area as a whole, as the treatment effect is negative with respect to both weekday and weekend average ridership. The treatment effect on BART stations in low-density neighborhoods, however, is not statistically significant for either weekday or weekend average ridership. This suggests that there is no relationship between bike sharing and BART ridership in low-density neighborhoods.

In no case is the coefficient on the treatment variable positive and significant. In other words, the substitution effects that would drive BART ridership down overshadowed any complementary effects, such as the solving of first- and last-mile problems. However, it is important to note that the results presented are limited in their ability to explain the specific effects underlying the treatment effect. For example, Walk Score® does not provide or document historical data, so the separation of BART stations into high- and low-density categories is done using a walkability index that was generated for a single point in time for each station in the dataset. However, it could be the case that those individuals choosing to live in less-dense neighborhoods have fundamentally different preferences than those individuals choosing to live in more-dense neighborhoods. Without a walkability index that changes over time, it is not possible to determine the causal effect of density on the relationship between BART and bike sharing. Furthermore, these regressions do not account for the intensity of the treatment. It is likely the case that high-density neighborhoods have many more bike-sharing stations than low-density neighborhoods, but treatment in these regressions is an unweighted binary variable based on the presence of a bike-sharing station near a BART station. The potential effects of this difference in treatment intensity are not captured.

Section V: Conclusion

This thesis examined the effect of the 2017 bike share expansion on BART ridership. The results suggest that the bike share expansion slightly decreased BART ridership overall, with large decreases to weekend BART ridership and no impact to those BART stations located in low-density neighborhoods. The large negative treatment effect on weekend ridership suggests that leisure trips entail relatively more substitution between BART and bike sharing.

Transportation is an indispensable facet of the economy; however, transportation causes significant negative externalities. The transportation sector is the single largest source of greenhouse gas emissions in the United States, and traffic collisions account for nearly 40,000 deaths per year. Most of these negative externalities are caused by cars, and other forms of transportation, such as rail and bicycling, are relatively more environmentally friendly and safe. Policymakers often seek to reduce reliance on cars in order to reduce the damages from automobile-related negative externalities. Many urban planners argue that bike sharing systems could increase access to public transit by solving first- and last-mile problems, which would reduce reliance on cars. However, evidence on the relationship between public transit and bike sharing is mixed at best. Because of the importance of both transportation and reducing automobile-related externalities, research into this relationship is needed to better inform transportation policy.

While the results in this thesis contribute to the existing literature on the relationship between bicycles and public transit, there are unexplained issues that are important for policy, and this should be explored. For example, the impact of urban form (degree of density) on the relationship between bike sharing and public transit could be important. If lower density neighborhoods benefit relatively more from bike sharing with respect to its integration with public transit, bike sharing could serve as a method of increasing the economic viability of public transit systems in rural areas which might have previously been unable to adequately support a public transit system. While this thesis explores how density might change the relationship between bike sharing and BART, the limitations of the data make it difficult to reveal the causal effect of density on the relationship in question. Further research into the impact of urban form is needed to better understand the efficacy of bike sharing at solving first- and last-mile problems.

Another avenue of future research is how bike sharing might impact BART ridership specifically with respect to welfare. While this thesis finds significant substitution overall, it could be the case that the bike share expansion benefits the poor relatively more than it does the wealthy. Typically, public transportation systems are used disproportionately by the poor, and poor individuals are far less likely to own cars than wealthy individuals. It could be the case that bike share expansion reduces overall trip costs relatively more for the poor than for the wealthy despite the overall negative treatment effect on ridership. This is an important factor to consider when analyzing transportation policy.

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