Urban Bicycle Infrastructure and Gentrification: A Quantitative Assessment of 46 American Cities

Gabriel Morrison

A thesis
submitted in partial fulfillment of the
requirements for the degree of
Bachelor of Arts
(Geographical Sciences)

April 2021

Table of Contents

List of Figures

List of Tables

Acknowledgements

Chapter 1

Abstract

In recent years, cities across the United States have expanded their bicycle infrastructure. In some instances, community members and local politicians have criticized these developments and noted a link between bicycle lanes and gentrification. In response, recent studies have assessed the quantitative associations between bicycle infrastructure and gentrification in a few large cities. Their results have been mixed but generally support residents' claims of linkages between gentrification and bike infrastructure. However, research is often limited to a handful of large central cities, mostly in the United States.

This thesis assessed the associations between gentrification and bicycle infrastructure such as bike lanes and off-street trails and paths in 46 large American cities. Specifically, it used contemporary municipal bicycle infrastructure data aggregated to the census tract level. It conducted multivariate regression analyses to identify the cross-sectional associations between gentrification and other socio-economic indicators and the presence of bike infrastructure. It compared these associations by city size and geographic region. It found substantial evidence that gentrifying tracts had higher rates of cycling infrastructure relative to disadvantaged, non-gentrifying tracts. This trend was less pronounced in America's largest 5 cities, and there was substantial regional variation in both infrastructure coverage and relative levels when comparing gentrifying, non-gentrifying, and advantaged tracts.

Chapter 2

Introduction

Despite its widespread discussion within and outside academic literature, gentrification lacks an agreed-upon definition. Scholars have associated the term with a transition from owning to renting houses, a process of urban neighborhood "rediscovery," a valorization of old buildings and broader appreciation of urbanity relative to the suburban lifestyle, and the improvement of a neighborhood's infrastructure (Shaw, 2008). It is also associated with an urban, often minority, neighborhood experiencing an influx of new capital, leisure activities, and residents of a higher socioeconomic class and a different race, which is often White. This thesis uses Lance Freeman's (2005) conceptualization of gentrification which distinguishes gentrifying regions from advantaged and not gentrifying (i.e. disadvantaged) ones based on their location in central cities, median family income, recent housing development, change in housing prices, and change in average levels of educational attainment. A more formal presentation of Freeman's classification can be found in the Methods section.

Though scholars disagree on a definition, many recognize it has potentially substantial negative consequences. Gentrification is commonly associated with displacement, or long-time residents being forced out of a neighborhood due to increasing prices, in both academic scholarship (Elliott-Cooper et al. 2020; Marcuse 1986; Shaw 2008) and popular media (Dragan et al. 2019; Freeman 2005). Notably, when British sociologist Ruth Glass coined "gentrification" in 1964, she contended that it led to price increases and social character changes that displaced residents (Shaw 2008). Beyond displacement, gentrification can also restrict the range of acceptable neighborhood behaviors, and gentrification can frustrate long-time community members who feel slighted by their lack of input in neighborhood changes (Freeman, 2006, p. 196). These dynamics are more extensively discussed in the Literature Review.

Critics of the development of cycling infrastructure in underserved neighborhoods make arguments that fall in line with these more general concerns about gentrification. For example, some residents and politicians of neighborhoods experiencing investments in bike infrastructure also viewed this development as a potential *cause* of gentrification and displacement (Hoffmann, 2016; O'Sullivan, 2021; Kramer, 2020). Hoffman (2016) and Lubitow et al. (2016) documented

how the development of bike lanes in minority neighborhoods in Portland and Chicago were seen as symbols of gentrification and how the city government's focus on this infrastructure failed to respond to those communities' wants and needs. This critique falls in line with the more general notion that gentrifying neighborhoods fail to meet long-time residents' desires. In short, critics of the development of cycling infrastructure offer commentary that follows the broader criticism of gentrification, a dynamic upon which I elaborate in the Literature Review.

In this thesis, I assess the cross-sectional associations between gentrification and bicycle lane development in 46 of the largest cities in the United States. This is both a gap in the academic literature and a highly salient issue. Some recent studies (Flanagan et al., 2016; Braun, 2018) have conducted similar research on the association between cycling infrastructure and gentrification, but their scope has only included a handful of major cities like Chicago, Portland, Oakland, and Minneapolis. This scope is limited, so the extent to which gentrification and cycling lanes co-occur across large cities in the United States remains unclear. Moreover, as discussed above, the co-occurrence of gentrification and the development of cycling infrastructure can be fraught and incredibly frustrating to local residents, making it salient even if the causal relationship between cycling lanes and gentrification remains unclear (Hoffman, 2016; Lubitow et al., 2016). This research is also relevant from an equity-oriented perspective because it compares presence of a public amenity across different communities in large American cities. Thus, it is important to study these associations at a broader scale across the United States.

Following Braun (2018), I used 2015-2019 American Community Survey data to assess whether a specific census tract was gentrifying. I collected municipal-level spatial bicycle infrastructure data from 2015 onward in each of the cities studied and used multi-variate Ordinary Least Squares (OLS) regressions to assess the associations between census tracts' gentrification status and their level of bicycle infrastructure, as measured by distance of bicycle lanes or off-road trails per square kilometer. I controlled for distance to the central business district, population density, and number of young residents, all potential predictors of cycling infrastructure, and also added a term for the number of minority residents in the region. I then compared similar models for cities of different sizes and in different regions of the United States.

The results suggest that there is substantial spatial heterogeneity in the distribution of census tracts in major American cities. Overall, gentrifying tracts tend to have greater levels of cycling infrastructure than both advantaged and not gentrifying tracts. When controlling for other

factors, gentrifying tracts still have on average higher levels of cycling infrastructure relative to not gentrifying tracts, but no statistically significant differences with advantaged tracts. When considering cities by size, extremely large cities (MSA population > 7 million) tend to have less infrastructure than other cities. When considering cities by region and controlling for other factors, non-gentrifying tracts in the Interior West and South have statistically significantly lower rates of cycling infrastructure.

This research built upon the existing literature on bicycle infrastructure and gentrification. Specifically, it supported the findings of Braun (2018), Tucker and Manaugh (2018), and Flanagan et al. (2016) by documenting the inequitable distribution of bicycle infrastructure by race and by neighborhood gentrification status. Notably, these findings contrast with those of Houde et al. (2018) who studied Montreal and the surrounding region. The results also advanced the qualitative literature and media reports' identification of cases in which gentrification and bicycle infrastructure development co-occur by assessing the scope of this issue in major metropolises across the United States.

Chapter 3

Literature Review

This literature review aims to delve further into the issues discussed in the Introduction. Specifically, it will begin by describing cycling trends in the United States and the process by which new cycling lanes are allocated. It subsequently deepens the discussion about the consequences of gentrification by considering both displacement and other issues. It provides a broader context to criticism of bike lanes in conjunction with gentrification by discussing New Urbanism and "the creative class." This discussion serves to contextualize criticisms of the development of cycling infrastructure which I consider more in depth here.

Bicycling in the United States

While bicycling in the America in the last decade has served as a relatively steady source of transportation, rates of cycling tend to be broken down by demography and geography. National Household Travel Survey (NHTS) data suggest that between 2009 and 2017, about 1% of all trips were taken by bicycle. This same data finds that women are under-represented as cyclists, making up only 28.0% of bicycle commuters. Data from the 2005 to 2016 American Community Surveys (ACS) suggests that about 0.5% of all commutes are taken by bike. 2008-2012 ACS data indicates an inverse relationship between income and bicycling; about 1.5% of commuters earning less than $10,000 biked to work, whereas only about 0.5% of workers earning greater than $200,000 cycled to work during the same time. While the 2010 Decennial Census suggests that about 28% of Americans are non-White, only about 20% of bicycle trips were made by cyclists of color based 2009 and 2017 NHTS data. Southern states make up eight of the ten states with the lowest rates of cycling to work, demonstrating spatial heterogeneity in rates of cycling as a mode of transportation (see Figure 1) (McLeod et al., 2018). In short, cycling rates vary across the country, White people tend to cycle more, and extremely high earners commute by bike less.

Bike Lane Distribution:

At least three theories explain the distribution of the development of bicycle lanes in the United States. First, bicycle infrastructure could follow, and potentially be caused by, a region becoming more socio-demographically advantaged (Braun, 2018). This theory is consistent with findings that urban planning and infrastructure development responds to the desires of advantaged, often White, residents (Hoffmann, 2016; Braun, 2018). Second, bicycle infrastructure development could precede, and potentially induce a neighborhood to experience an influx of advantaged residents (Braun, 2018). This follows Richard Florida's prescription of developing successful cities by attracting well-educated white-collar workers with urban amenities like cycling lanes (Florida 2002; Braun, 2018). Finally, bicycle infrastructure could develop as a consequence of more "traditional" demand factors that depend upon urban form and demographics like high percentages of young residents, population density, and proximity to a city's urban core (Braun, 2018).

Figure 1: Share of Commuters who cycle to work (2016 ACS data)
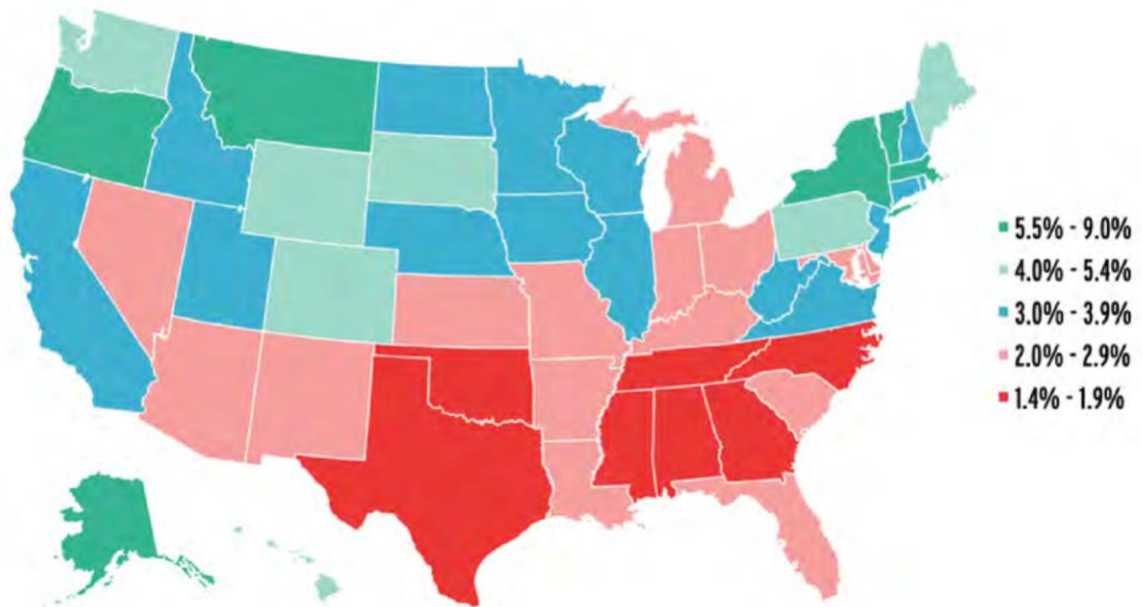
From McLeod et al., 2018, page 215

Gentrification and Displacement

The causal relationship between gentrification and displacement has been hotly contested in academic planning and sociological literatures. Some scholars find gentrification does not generally cause displacement (Henig, 1980; Vigdor, 2002; Freeman and Braconi, 2004; Dragan et al., 2019). However, much of this research has been criticized (Slater 2009; Newman and Wyly, 2006; Marcuse, 2005). Other scholarship has found statistically significant, if relatively small in magnitude, evidence of gentrification-induced displacement, particularly in more recent years (Newman and Wyly, 2006; Brummet and Reed, 2019; Owen, 2012). Finally, other research takes a different stance on the issue, suggesting that there is no causal relationship except in major cities like London (Freeman et al., 2016), that displacement can be an *antecedent* to gentrification (Billingham, 2017), or that concentrated poverty, not gentrification-induced displacement, is crucial to study when seeking to ameliorate the plight of the urban poor (Cortwright & Mahmoudi, 2014).

Other Impacts of Gentrification:

Despite quantitative social science's mixed record definitively identifying gentrification as a major driver of displacement, the literature recognizes the harms of gentrification and displacement. Elliott-Cooper et al. (2020) eloquently argued that displacement is a form of systematic violence that can lead to psychological and even post-traumatic stress. Freeman, (2006) classified gentrification as "repressive and restrictive." In two historically Black New York neighborhoods, he specifically noted that activities like congregating on street corners, barbequing in parks, and publicly consuming alcohol became unacceptable as the neighborhoods underwent gentrification (Freeman, 2006, 196). Freeman (2006) also described "the specter of displacement," observing that the fear of displacement was also harmful to gentrifying neighborhoods, regardless of whether displacement actually occurred (p. 162-164). Neighborhood changes associated with gentrification also frustrated some long-time residents who were perturbed by their lack of control over their community (Lubitow et al., 2016; Tavernise, 2011; Badger, 2020; Mirk, 2012).

Even so, gentrification does bring some benefits. Theoretically, it can mitigate segregation by allowing the mixing of races and classes (Newman & Wyly, 2006). Relatedly, it can allow middle class Blacks to live in middle-class neighborhoods rather than being forced to

choose between well-off White or disinvested Black communities (Freeman, 2006, p. 197). It can also allow low-income children in poorer families who remain in gentrifying neighborhoods to experience major positive educational and professional outcomes (Chetty et al., 2016; Dragan et al., 2020). Residents in gentrifying neighborhoods, particularly in those that had been extremely disinvested, likely also experience increasing access to neighborhood services and amenities (Freeman, 2006, p. 160). In other words, gentrification has some potentially positive outcomes.

Theoretical Foundations: New Urbanism and the "Creative Class"

New Urbanism and the notion of the "creative class" support bike infrastructure development in cities. However, both philosophies have been criticized for their lack of equity in general and, specifically, with respect to bike lanes.

New Urbanism supports sustainable, mixed-use urban form and is supportive of bike infrastructure. Generally, New Urbanism encourages neighborhoods with compact form, close proximity between jobs and residences, decreased usage of cars, and the fostering of unique neighborhood identities (Day, 2003; Grant, 2011). The Charter of the New Urbanism encourages the creation of bicycle networks to reduce car usage (Congress for the New Urbanism, 2000). New Urbanism is important in practice; New Urbanist ideas were crucial to the Department of Housing and Urban Development's Hope VI program as well as the plans and regulatory codes of numerous cities across the United States (Bohl, 2000).

New Urbanism broadly has come under fire for equity-related issues. New Urbanist scholar Emily Talen wrote that neighborhoods that subscribe to Jane Jacobs's tenets, which served as part of the inspiration for New Urbanism, can experience gentrification and displacement and that physical urban development needs to be partnered with anti-displacement policy (Talen, 2012). Day (2003) and Larsen (2005) echoed this argument, contending that the New Urbanist "toolkit" relies almost exclusively on physical changes to the built environment and is, therefore, less responsive to communities' other concerns. Finally, New Urbanists' traditional modes of community engagement may not be tailored for communities considering neighborhood changes (Day, 2003). In other words, critiques of New Urbanism have pointed to the fact that its neighborhood improvements can lead to displacement, may not respond to

12

existing community-members' most pressing needs, and could fail to engage the community effectively.

The conception of the "creative class" presents another modern and influential view of successful cities and encourages bike infrastructure. In his 2002 book *The Rise of the Creative Class*, Richard Florida defined the "creative class" as people with jobs that are not blue collar, in the service industry, or agriculture-related (2002, p. 328). Florida contended that the creative class fuels economic growth, so cities should seek to attract them with retail and entertainment amenities (2002, 223-232, 249-250). Florida also identified the creative class's strong association with bicycling (2002, p. 172-173, 181-182). Ideas about the "creative cities" have strongly influenced policy-decisions in many major cities including London, Tampa Bay, Silicon Valley, Auckland, and Brisbane (Atkinson & Easthope, 2009).

Florida's concepts have been strongly criticized, in part for equity-related issues. Edward Glaeser analyzed Florida's own data and concluded that his policy prescriptions are unsubstantiated (Glaeser, n.d.). Florida himself acknowledges that creating places attractive to the "creative class" could raise housing costs (Peck, 2005). Moreover, meeting the needs of the "creative class" could simultaneously expand the poorly paid service industry who would respond to "creatives'" desires (Peck 2005). Wilson & Keil (2008) came to similar conclusions, arguing that Florida's ideas only act as a new rationale to encourage public policies that privilege the elite. They added that they ignore cities' true problems: inequality, segregation, and unstable economies (Wilson & Keil, 2008). In sum, Florida's (2002) ideas have been criticized methodologically and substantively for their potential to cause displacement and for their lack of consideration of the poor.

New Urbanism, the Creative Class, and Bicycle Infrastructure

The broad critiques of New Urbanism and tailoring to the "creative class" apply specifically to the development of bicycle infrastructure. Former Chicago Mayor Rahm Emmanuel's $150 million plan to improve Chicago's bike infrastructure was criticized for the city's not consulting communities in which the new bike lanes were to be built (Lepeska, 2011). Then Mayor Emanuel pitched this development as a way to attract new tech companies and start-ups, an almost explicit allusion to Florida's "creative class" (Lubitow et al., 2016). Some Black residents in a historically minority and underserved but gentrifying neighborhood in Portland

contended that the city only invested in the neighborhood when White people relocated there (Hoffmann, 2016; Davis, 2011; Goodyear, 2011). Hoffman (2016) observed that the development did not respond to the needs of long-term residents, one reason why bike lanes antagonized the community. Since the onset of the global COVID-19 pandemic, a number of large cities have transformed their urban spaces, including creating slow streets that are bikeable and planning new bike lanes, but this rapid urban change often has not included the desires of marginalized residents (Kramer, 2020; Badger, 2020). In short, the development of new bike lanes has been criticized for not consulting underprivileged residents, failing to consider their wants and needs, and potentially inducing gentrification and displacement.

Bike Lane Criticism and Association with Gentrification

In the past decade and, in particular, since the onset of the pandemic, local politicians and community members in major cities across the United States have criticized bike infrastructure development for its potential to cause gentrification and displacement. A 2011 *New York Times* article reported that some poorer residents of Washington D.C. saw the city's revitalization, which included building bike lanes, as "code for efforts to drive them out" (Tavernise, 2011). Some local Portland communities reportedly called the development of new bike lanes through a historically marginalized and minority community "white stripes of gentrification" (Davis, 2011). At the CityLab 2021 Conference, urban designer Jay Pitter argued that marginalized communities resist bike lane development because they "spur gentrification" (O'Sullivan, 2021). In Washington D.C., Ward 8 Councilmember Trayon White argued that new bike lanes "force aspects of gentrification and displacement" (Kramer, 2020). In other words, politicians and community members have also criticized bike lane development and argued that it is associated with gentrification.

Quantitative Studies Assessing Equity and Bike Infrastructure

While a relatively new sub-field, four recent studies have assessed various aspects of bike infrastructure and their associations with gentrification, generally finding some small but significant positive correlations. In a longitudinal study with data from 1990 to 2015, Braun (2018) studied Chicago, Minneapolis, and Oakland. In Chicago and Oakland, Braun (2018) found associations between bike infrastructure and areas that were either advantaged or

gentrifying (as opposed to those that were disadvantaged). The results in Minneapolis were more mixed, but the overall evidence supported the linkage between bike lanes and gentrification (Braun, 2018). When running lagged regressions, Braun (2018) found that gentrification preceded bike infrastructure in Chicago, and gentrification and bike lane development occurred at the same time in Oakland. Flanagan et al. (2016) studied bike infrastructure, including inexpensive bicycle share stations, in Chicago and Portland from 1990 to 2010, concluding that bike infrastructure tended to be invested in gentrifying or privileged areas. In Montreal and two neighboring cities, Houde et al. (2018) found that lower-income residents have notably good access to bicycle infrastructure and that this infrastructure was increasingly accessible to immigrants. However, in Rio de Janeiro and Curitiba, Brazil, bicycle infrastructure was highly concentrated in wealthy areas (Tucker & Manaugh, 2018). In short, in recent years, a handful of quantitative studies have begun to document associations between bike lanes and privilege and generally, but not exclusively, find positive associations.

Other studies have considered the disparities in distribution of bike lanes in major American cities along other lines. For example, Braun (2018) also collected spatial data on bicycle infrastructure in 22 major American cities and used regressions to assess the extent to which socioeconomic indicators were associated with greater bicycle infrastructure. She controlled for population and employment density, distance to a central business district, young residents, and commuters who used a bicycle. She found associations between less bicycle infrastructure and some indicators of disadvantage, like lower educational attainment and higher proportions of Hispanic residents, but not with others, such as lower income, higher poverty, and proportions of Black residents. Hirsch et al. (2017) studied the clustering of bicycle lanes and trails, as well as bus transit services and parks, in Birmingham, Minneapolis, Oakland, and Chicago, finding associations between the construction of bike lanes and falling unemployment. Hirsch et al. (2017) also found some evidence of clustering in the development of bike lanes in dense urban areas while paths and trails tended to see increased development in the periphery of the cities in their study.

Chapter 4

Methods

This section is divided into seven distinct subsections. The first considers the selection process for the 46 cities included in this thesis, the decision to use the census tract as the unit of spatial analysis, and the methods utilized to select census tracts for each of those cities. The second considers the spatial and temporal scope of the project. The third presents Freeman's (2005) gentrification classification scheme and how I applied it to more recent and slightly different data. The fourth and fifth describe the processes of collecting and handling other covariate data and cycling lane spatial data. The sixth presents my cleaning and aggregation of the cycling lane data. The last subsection describes the analysis process. Also, note that all work was conducted in R.[1]

City Selection and Classification:

I limited this study to considering central cities for two reasons. First, Freeman's (2005) gentrification indicator identified tracts as gentrifying only if they reside in a central city. This will be discussed more fully later in the gentrification subsection. Second, many suburban municipalities did not have publicly available cycling data, and the task of collecting cycling data from many suburban municipalities would have been too time-intensive for the scope of this work. I also limited the central cities in consideration to those in Metropolitan Statistical Areas (MSAs) with populations greater than 1 million according to 2019 1-year ACS data. This cutoff is somewhat arbitrary but necessary to capture the dynamics in cities rather than towns. I filtered out the eight cities which met this population criterion but whose bicycle data I could not find. The search for bike lane data is described later in this section. I also removed Tucson, AZ due to its bicycle data being from 2014, before the start of the five-year ACS estimates I used to classify the tracts as gentrifying (see the gentrification subsection). This left 46 cities.

---

[1] Scripts can be found here: https://github.com/Deckart2/bikes_thesis

I classified each of these 46 cities by size and region. I divided cities into three groups based on their 2019 1-year MSA population. I classified cities in MSAs with > 7 million people as "extremely large cities," 3-7 million as "large cities," and < 3 million as "medium cities." I also classified the cities into one of five geographic regions in the US: West Coast, South, Southwest, North East, and Midwest. The cities and their size and region can be seen in Appendix A.

Spatial and Temporal Scope:

I used census tracts as the unit of analysis. This followed Flanagan et al. (2016). Notably Braun (2018) used the smaller block groups which theoretically gave more resolution to the data. However, when considering the spatial scale, I followed Folch et al.'s (2014) suggestion to consider the coefficient of variation (CV), an estimate's standard error divided by the estimate itself. Many estimates had CVs of either "medium reliability" (between .12 and .40) or worse (greater than .40) at the block group level, leading me to choose to use the census tract level (Folch et al., 2014).

I used geo-computational methods to select each city's census tracts. I began with a shapefile with 2010 census tract boundaries for the entire US from IPUMS. For each of the 46 cities studied, I downloaded a polygon spatial data layer to identify city limits. Many cities had explicit datasets for city boundaries but when those were unavailable, I downloaded other polygon datasets, like, for example, city councilmembers' districts, which covered the extent of the city.[2] I then performed spatial unions on each of the 46 cities' polygon datasets to convert those datasets into a single multi-polygon layer. I joined all cities' boundaries into one dataframe and buffered each by 125 meters, selected all census tracts strictly within the buffered city boundaries, and assigned those tracts to their respective city. 125 meters was chosen because it effectively selected the census tracts of representative cities Chicago, Washington D.C. and Portland. Once filtering the census tracts to include only those in the cities of interest, I joined that data to the non-spatial ACS data.

I used this method for two reasons. First, city data portals did not uniformly report the census tracts in their city, so I wanted to use a more universal selection method. Second,

---

[2] The specific sources of this data can be found here: https://tinyurl.com/morrisonthesis

performing selection using intersects methods (i.e. st_intersects in R's sf package's parlance) identified census tracts largely outside of city boundaries but with small portions of overlap inside the boundaries.

This thesis solely focuses on cross-temporal associations. As noted above, I use only cycling data from 2015 onwards. Additionally, the gentrification index, discussed more fully below, classifies tracts using ACS data from 2015-2019.

Gentrification:

To identify gentrifying tracts, I generally followed Braun (2018) in using Freeman's (2005) method. Freeman considered two years 10 years apart[3] and used five criteria to classify a tract as gentrifying. These were that the census tract:

1. Was located in the central city of a region
2. Had a median family income less than the MSA's median family income in the first year
3. Had a proportion of housing stock built in the 20 years preceding the first year lower than the median proportion of housing stock built for the MSA during those same 20 years
4. Had an increase in percentage of residents ages 25 or more with a bachelor's degrees that was higher than the rise in the MSA's percent increase in residents ages 25 or more with bachelors degrees in the ten-year time period
5. Had a real increase in housing prices in the ten-year time period

All tracts considered in this study meet the first criterion. If a tract did not meet either of the second or third criteria, it was classified as "advantaged" and, therefore, ineligible to gentrify. Tracts that met the first three criteria but not the last two were called "not gentrifying," and only tracts that met all criteria were deemed "gentrifying." While I use the descriptor "not gentrifying," these tracts should be considered disadvantaged regions in their cities given that they had some combination of low median family incomes, housing investment, increases in educational attainment and increases in housing prices.

---

[3] The 10 year separation comes from Freeman's usage of the census.

It should be noted that my measure of gentrification varies slightly from Freeman's in that he uses Decennial Census data which has a 10-year interval, and this thesis's 2006-2010 and 2015-2019 5-year ACS estimates have a slightly shorter interval of effectively 9 years. I used 2015-2019 data because it is the most recently updated ACS data available at the time of writing this thesis. While 2005-2009 ACS data exists, NHGIS noted that "no TIGER/Line files represent the actual set of tracts… identified in 2005-2009 ACS tables, so NHGIS does not provide boundary files for the '2009 vintage' of these results" (goray). To avoid addressing this issue and the potential errors associated with cross-walking data from 2000 to 2010 census tracts, I used 2006-2010 data which, like the 2015-2019 data, exists at the 2010 census tract scale.

Figure 2 illustrates the process of classifying tracts as gentrifying, advantaged, and not gentrifying. Appendix B lists the number of tracts in each city that are gentrifying, advantaged, and not gentrifying.

Covariates:

I collected covariate data from two types of sources: an aggregated city center dataset created by Holian (2019)[4] and the 2015-2019 ACS.

From the 2015-2019 ACS, I also collected covariate data on the number of minority residents (i.e. all of those who were not classified as non-Hispanic White), total population, and total population ages 18-34. I divided the total population by the area of the census tract to compute population density.

Holian (2019) studied and aggregated different central business district (CBD) datasets. Notably, 1982 Census researchers identified CBDs in 385 cities, and researchers from the Federal Reserve (Fee & Hartley, 2012) converted more than 200 of those areas into points. For central cities not included in this study, Holian (2019) noted that one available alternative is using the city hall's geocoded location from an ArcGIS dataset that he also provided. Holian shared this data, as well as other identifications of CBDs, on his blog. For the 46 cities considered in this thesis, I use the point identified by Fee & Hartley (2012) if it existed or, otherwise, the ArcGIS geocoded city hall location. Saint Paul's city hall was not in either dataset, so I used Google Maps to identify the latitude and longitude of its city hall and inputted it

---

[4]Data downloaded here: http://mattholian.blogspot.com/2013/05/central-business-district-geocodes.html

manually. I then computed the distance between the centroid of each census tract and the point identified as the city center.

In summary, from Holian (2019) and the 2015-2019 ACS, I collected the following covariate measures: population density, population ages 18-34, distance to CBD, and number of minority residents.

Figure 2: Freeman's gentrification classification scheme
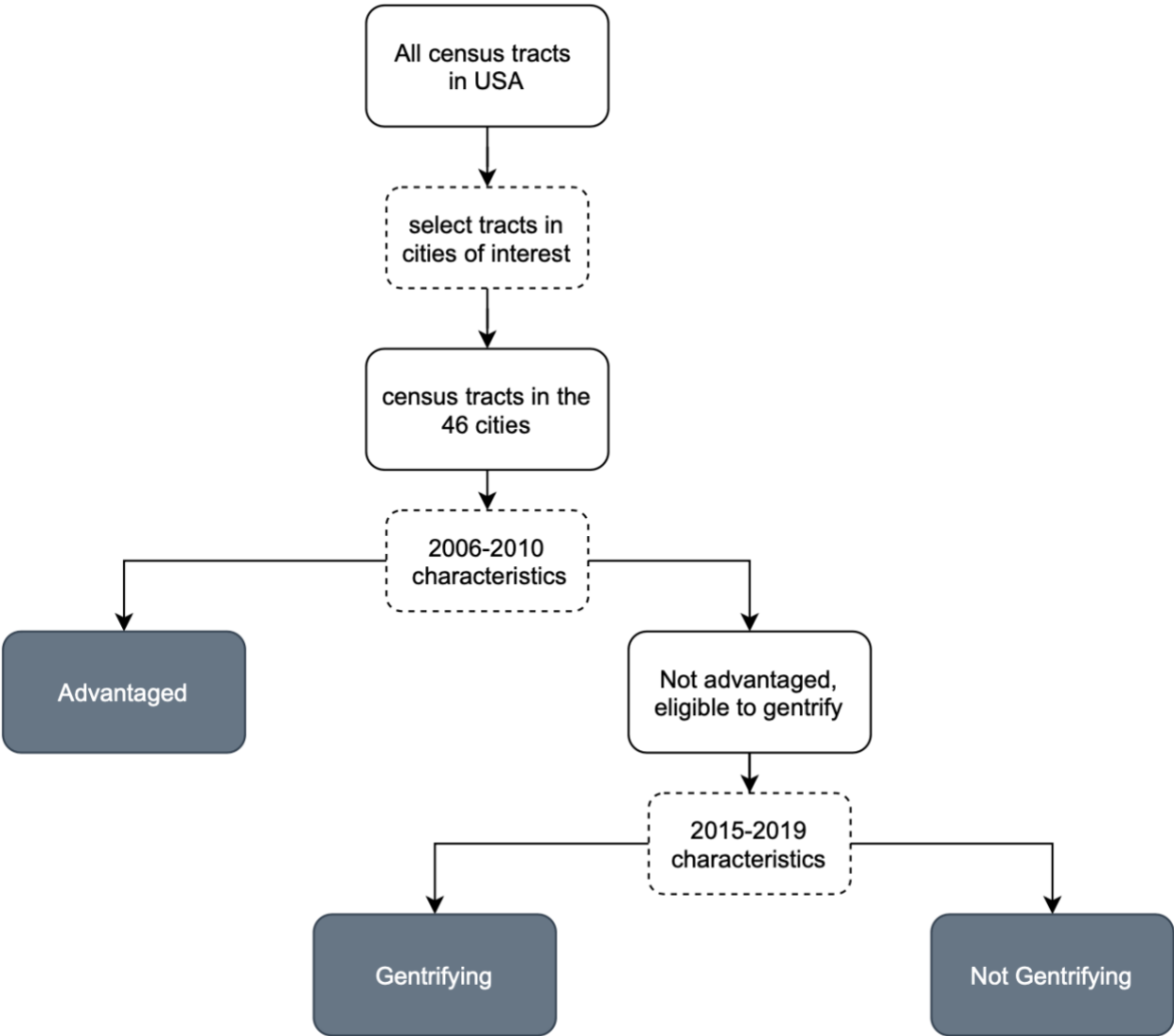
This chart modifies chart 4.2 1 from Braun (2018).

Bike Lane Data Geo-computation:

To gather information on each city's bicycle paths and trails, I first sought to find the spatial bike lane data via each city's website. Many large cities had open data portals with bike lanes and trails as unique spatial datasets (i.e. Shapefiles and more occasionally GeoJSON and Geodatabases with "linestring" or "multi-linestring" data indicating the location of bicycle lanes and paths). If I could not find such data, I sought similar or related data from larger government entities like counties and states. For example, to identify bicycle paths and routes for Salt Lake City, I downloaded Utah's road and trail data separately. Their road data noted whether a road had a bike lane, and their trail data denoted the type of path of interest. If I could not find data from a larger municipal entity, I reached out to city agencies requesting their data. Some cities had formal data request processes while, for others, I emailed representatives from the Departments of Planning, Transportation, or Engineering. Ultimately, through this process, I collected data from 46 cities. It should be noted that while I was unsuccessful in my attempt to collect data from 7 other cities, that data likely exists and very well could be publicly available; I was simply unable to find it or reach out to the correct city department or regional agency.

Table 1: Types of Bike Lanes

Type	Description:
Separated trails and paths	Paved or compact paths not on roads that tend to be multi-use and that bikers can use.
Protected bike lanes	On-street lanes with physical barriers separating the bike and car lanes.
Bike lanes	A designated, painted lane for bikers without physical barriers between car and bike lanes.
Shared lanes	Portions of the road designated for bikers to use but which other vehicles, either buses or sometimes cars and buses, may also use. This classification includes "sharrows."
Bike boulevards	Streets with physical infrastructure to slow traffic speeds but that lack "regular" bike lanes.

Cleaning the bike lane data was a heterogeneous process since each file had a separate structure. However, the general process involved selecting existing attributes to avoid including lanes that were planned to be built in the future. I also converted all shapefiles to a standard coordinate reference system (ESPG 2163). If the data source permitted, I grouped the bike lane data into one of five categories whose general descriptions are in Table 1. Again, due to the heterogeneity of data and the general lack of metadata, cities' descriptions of their bike infrastructure varied. Some cities had far more than these five bike lane categories, while others had less. Consequently, while the descriptions constitute a "best guess" for a unified classification scheme, such disparate data is inherently inconsistent. When I could not ascertain the type of infrastructure, I classified the type as "unknown." To aggregate the bike infrastructure data to the tract level, I first split all of the bike lane line data so that each segment was located in exactly one census tract. I then computed the distance of the lane. Finally, I standardized the data in each tract by dividing the total distance and distance of each lane type for all line segments by the area of the tract. This process can be seen in Figure 3. The first panel shows Chicago's census tracts and bike infrastructure relatively unprocessed. The second shows the bicycle infrastructure subdivided by the census tracts; this is perhaps most easily apparent in the southern portion of Chicago. The third panel shows the level of cycling infrastructure in each tract in units of meters of bicycle infrastructure per square kilometer in each census tract. The full lanes are also overlaid above the census tracts in the third panel.

Statistical Analysis

The dependent variables in this study were measures of bicycle infrastructure per census tract and in units of m/km^2, as described above. Dividing the distance of bike infrastructure by tract area responded to the modifiable areal unit problem. That is, without dividing by the area, tracts with larger areas would likely have had more bicycle infrastructure. Most of the t-tests and regressions conducted used the total bicycle infrastructure, the sum of all of the categories described in Table 1, but some considered each of the types separately.

22

Figure 3: Assigning Bicycle Lane data to Census Tracts in Chicago
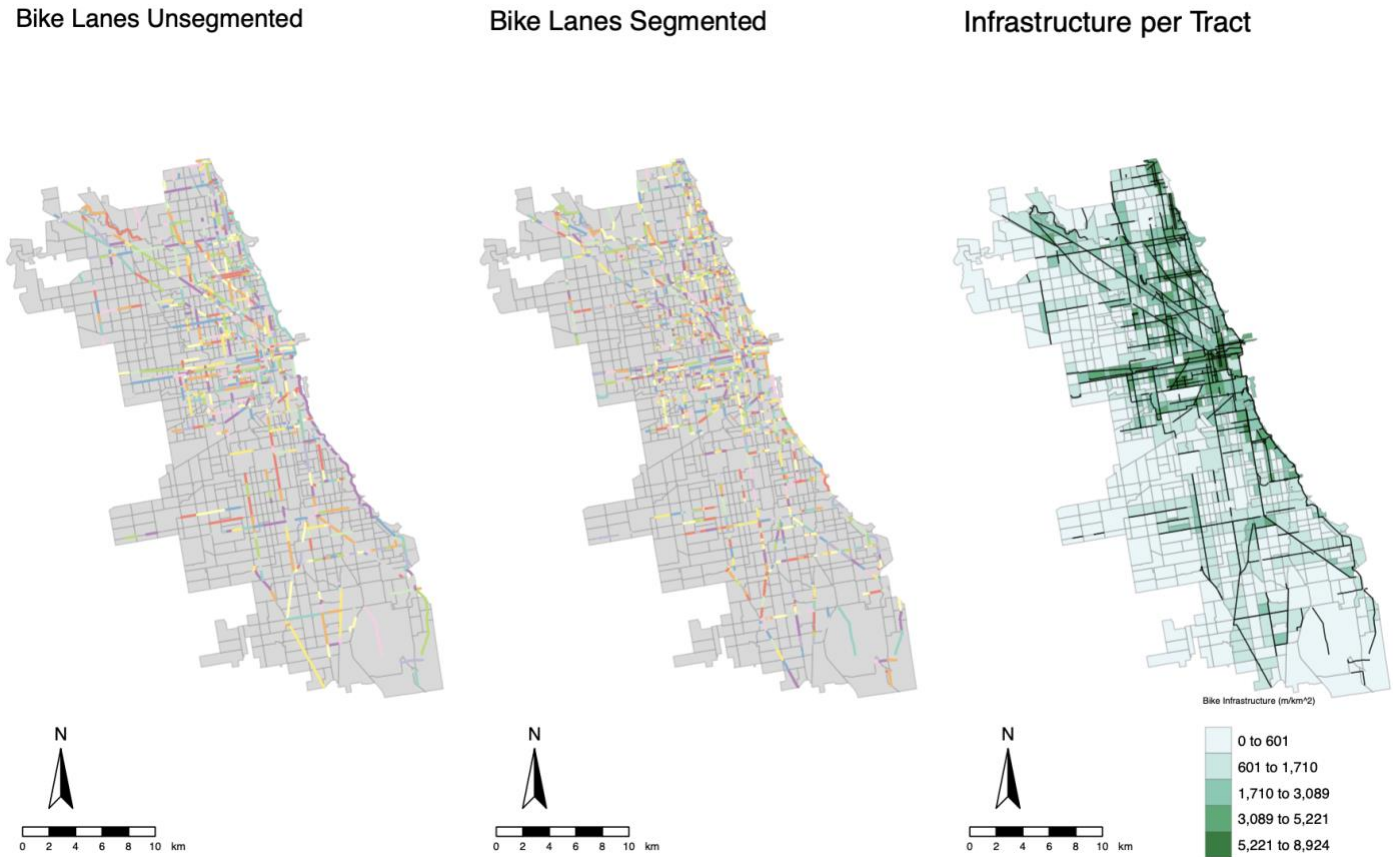
I first computed the level of bike infrastructure in m/km^2 in the census tract for all bike infrastructure and for each bicycle type (see Figure 6). I then conducted pairwise t-tests to assess whether the mean bicycle infrastructure measure in gentrifying, advantaged, and not gentrifying tracts were the same (see Appendix C). Specifically, I used a two-sided t-test that did not pool standard deviations or assume equal variance among groups. I used Bonferroni's method to control for conducting three tests and used a 95% confidence level. I conducted a similar analysis but with Holm's method and considered the cities by geographic region and size (Figure 7 and Appendix C, Figure 8 and Appendix C). Finally, I computed the percent difference between gentrifying and advantaged and gentrifying and not gentrifying tracts for each city and then plotted those values by city (see Appendix D).

I created an OLS multi-variate regression model in R considering all of the tracts across all cities studied (Equation 1). For each variable in the equation, i represents the i-th tract and j

indicates the j-th city. The dependent variable was the measure of total cycling infrastructure (in m/km^2), following Braun (2018). This is indicated as $Bike\ Inf_{i,j}$. The independent variables were two dummy variables representing the gentrification status. $not\_gent_{i,j}$ takes on 1 when the tract is neither advantaged nor not gentrifying and 0 when it is gentrifying. $advantaged_{i,j}$ takes on 1 when the tract is advantaged and 0 when it is gentrifying; thus, gentrifying tracts were the "base case" to which advantaged and non-gentrifying tracts were compared. The fourth through sixth terms of the equation represent control variables. These constitute what Braun (2018) classified as "objective demand factors," or urban form or demographic characteristics of regions that make them conducive to cycling. Specifically, they are population density, distance to the CBD, and number of residents ages 18-34. Dense areas near the CBD often are viewed as having higher demand for cycling, and young people (i.e. those 18-34) tend to cycle more (Braun, 2018). Braun (2018) and Flanagan et al. (2016) use all of these measures in their regression analysis; Braun (2018) used all three as controls and Flanagan et al. (2016) used two of the three as controls but number of young residents as part of their own gentrification index. Houde et al. (2018) included distance to the central business district as a control. I included a measure for the number of minority residents to capture an aspect of gentrification not included in Freeman's (2005) analysis. Finally, I again followed Braun (2018) in including dummy variables for each city. This is represented by u_j. This allowed the regression to assume different baseline levels of cycling infrastructure for each city.

Equation 1:

$$Bike\ Inf_{i,j} = \beta_0 + \beta_1 not\_gent_{i,j} + \beta_2 advantaged_{i,j} + \beta_3 pop\_density_{i,j} + \beta_4 dist\_to\_CBD_{i,j}$$
$$+ \beta_5 pop\_18\_34_{i,j} + \beta_6 minority_{i,j} + u_j + \epsilon_{i,j}$$

I also ran a number of smaller models on different subsets of cities by city region and size. These models looked similar to the model specification described above with the exception that I removed dummy variables; also, these models were applied to specific subsets of the data. This specification is shown in Equation 2.

Equation 2:

$$Bike\ Inf_i = \beta_0 + \beta_1 not\_gent_i + \beta_2 advantaged_i + \beta_3 pop\_density_i + \beta_4 dist\_to\_CBD_i$$
$$+ \beta_5 pop\_18\_34_i + \beta_6 minority_i + \epsilon_i$$

Chapter 5

Results

Visualization of Findings:

      Figure 4 illustrates how Freeman's (2005) index classifies the tracts in Washington D.C. and Nashville, Tennessee. Figure 5 shows the bicycle infrastructure measure. These cities are shown solely for demonstrative purposes to illustrate the results of the methods described in the previous section.

Figure 4: Washington D.C. and Nashville Gentrification Status
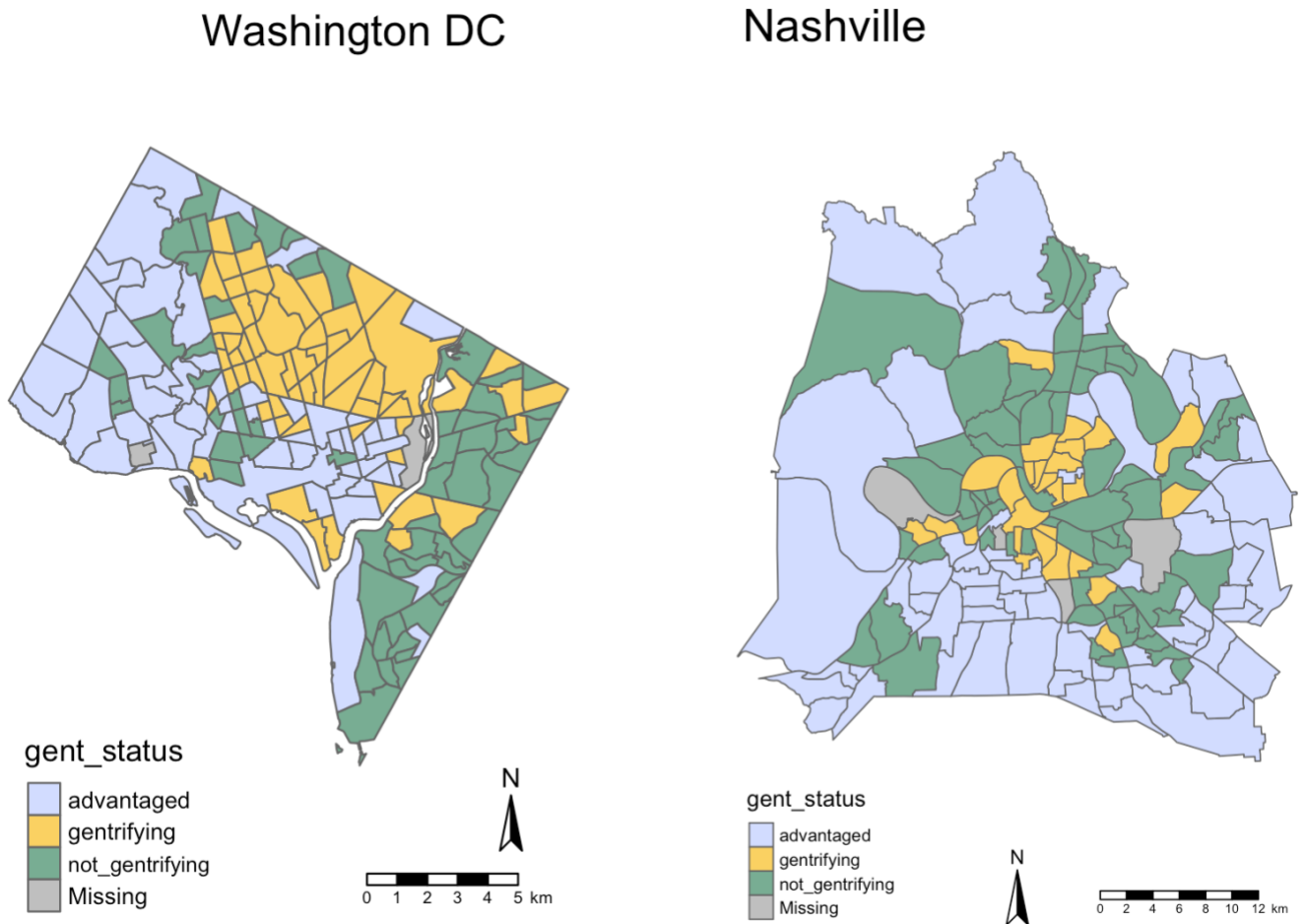
Figure 5: Washington DC and Nashville Bike Infrastructure (m/km^2)
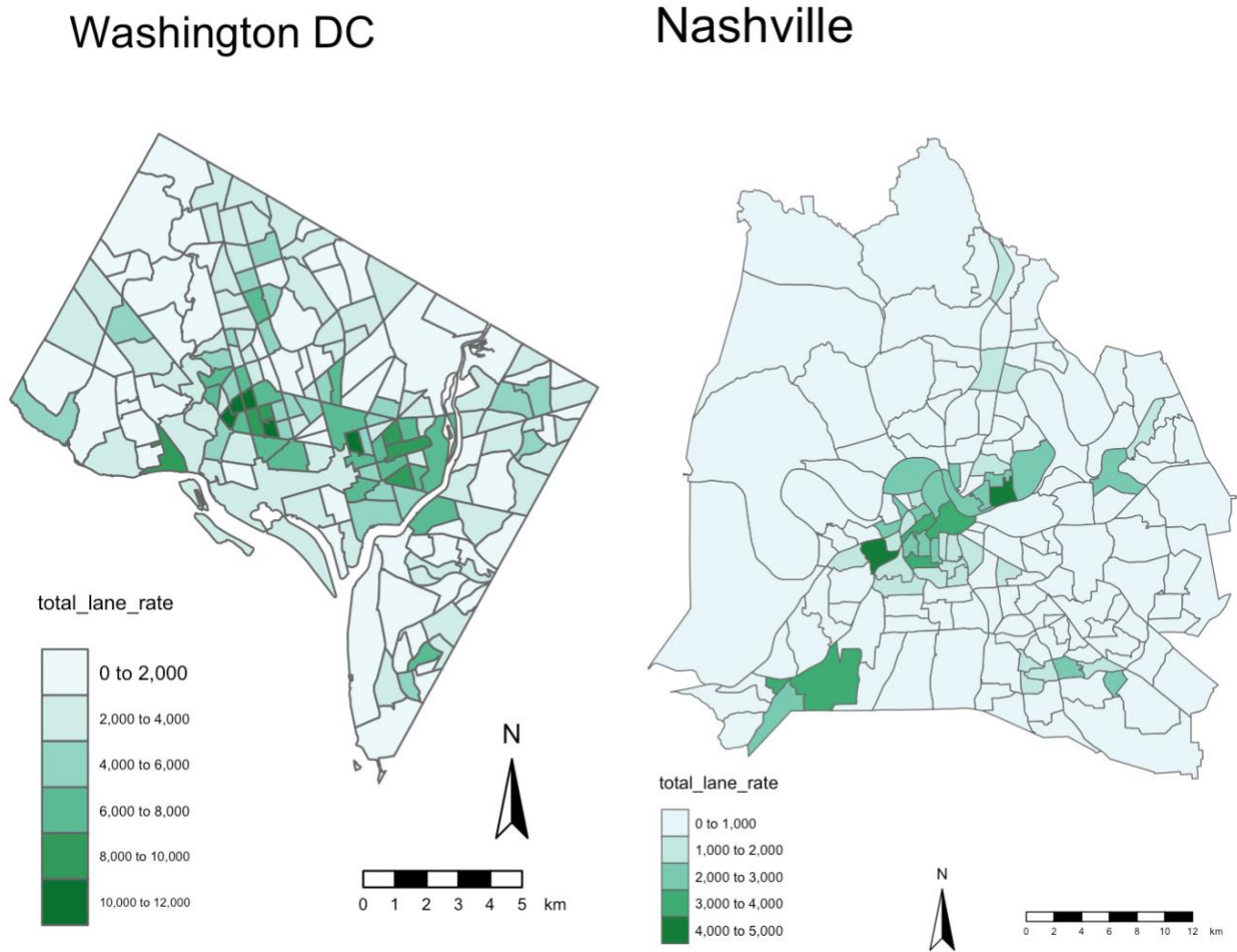
Statistical Tests Comparing Means:

Assessing the overall levels of bicycle infrastructure in the tracts by gentrification classification, the general trend was that gentrifying tracts had higher rates of infrastructure than advantaged tracts and not gentrifying tracts. This relationship was statistically significant ($p<.05$) when comparing overall bicycle infrastructure and four of the five specific sub-categories of lanes and paths; there is only a non-statistically significant difference between gentrifying and advantaged tracts with respect to their level of protected lanes. Advantaged tracts had statistically significantly higher rates of protected lanes and effectively the same number of paths and trails, (normal) bike lanes, and shared lanes but lower rates of bicycle boulevards. Figure 6 also showed the relative distribution of types of cycling infrastructure. Note that the exact results aggregated

by cycling infrastructure type, city size, and city region and the significance levels of the differences between the three tract types are reported in Appendix C. Additionally, the level of cycling infrastructure in each tract type for each individual city can be found in Appendix E.

Figure 6: Average Cycling Infrastructure by Lane or Trail Type
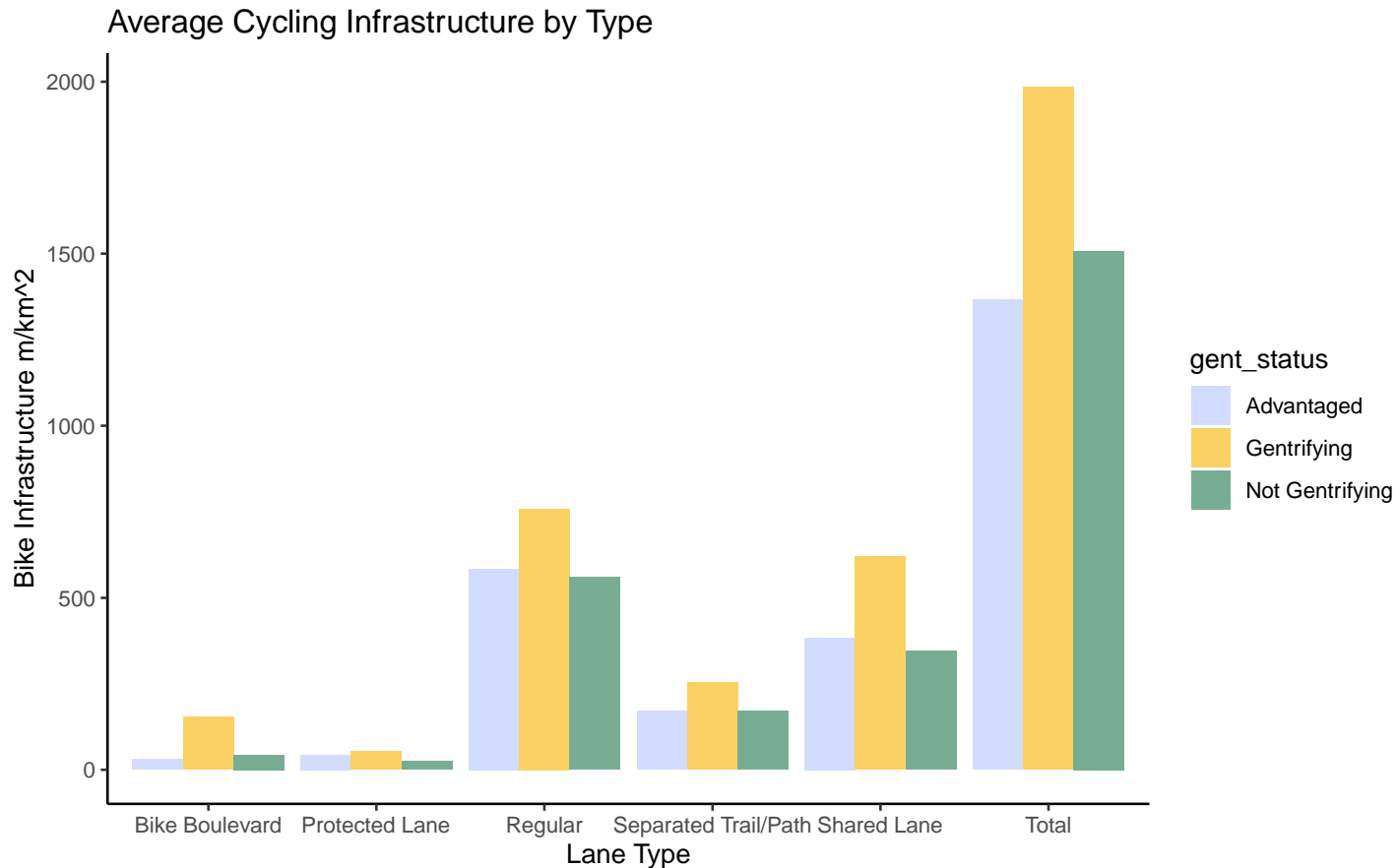
Analyzing bicycle infrastructure by gentrification status and city region was more ambiguous. Cities in the Midwest and on the West Coast had substantially higher rates of cycling infrastructure in all three gentrifying groups relative to the other three regions. Among the three groups of tracts, gentrifying regions in both the Midwest and West Coast had the highest rates of cycling infrastructure, and the differences between advantaged and not-gentrifying tracts was not statistically significant. Cities in the South, Northeast and Interior West all had lower overall rates of cycling infrastructure, and all differences were statistically significant, suggesting greater disparities in cycling infrastructure. In those three regions, gentrifying tracts had higher rates of cycling infrastructure relative to not gentrifying and advantaged tracts. In the Interior West and

South, advantaged tracts had higher rates of cycling infrastructure than non-gentrifying tracts, but in the Northeast, non-gentrifying tracts had higher rates of cycling infrastructure.

Figure 7: Average Cycling Infrastructure by City's Region in the US

Average Cycling Infrastructure by Region
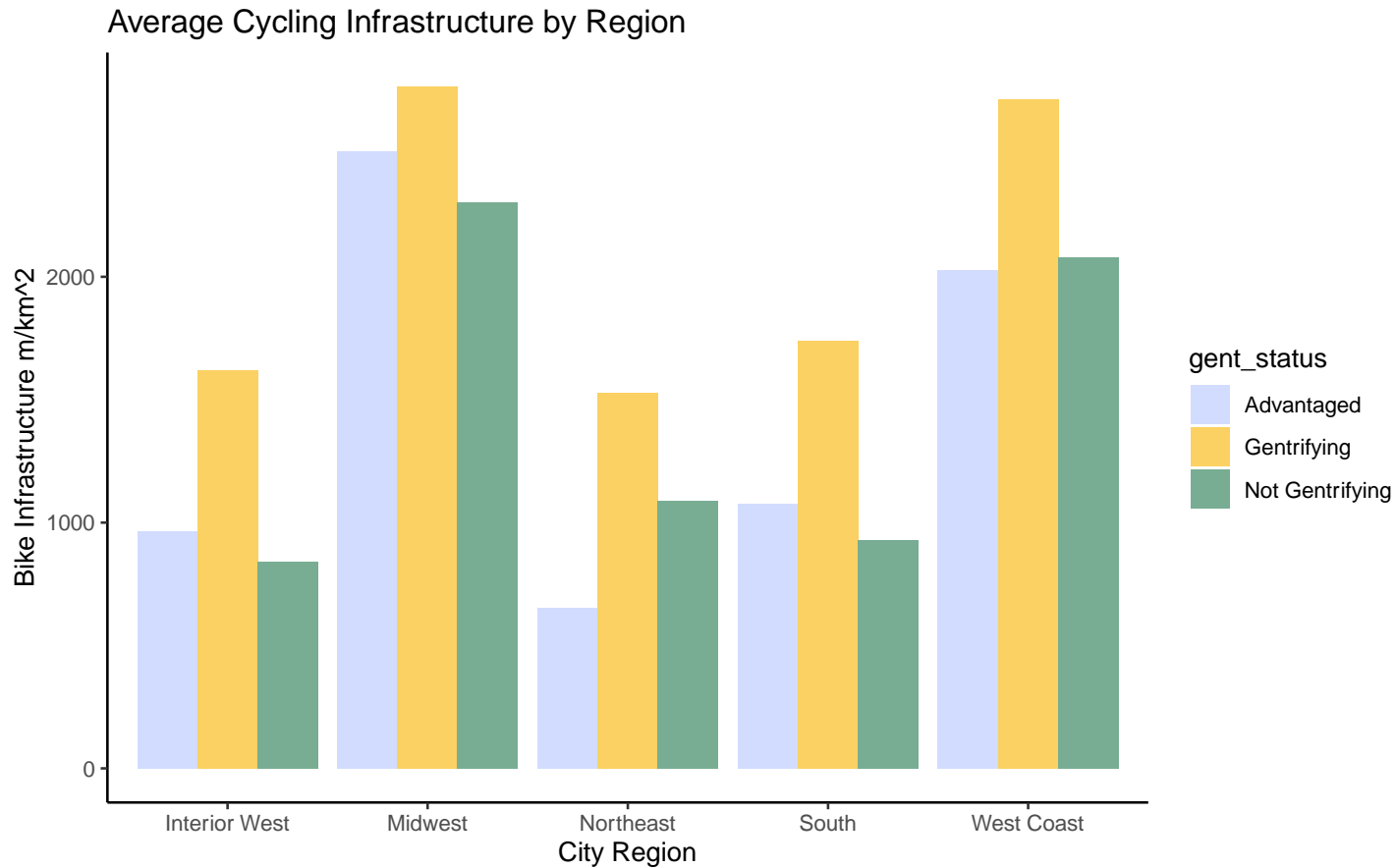
Extremely large cities had higher rates of cycling infrastructure in advantaged and not gentrifying tracts relative to gentrifying tracts, but far lower rates on the whole compared with medium and large cities. In extremely large cities, there was no statistically significant difference in the cycling infrastructure in each of the three groups. In large cities, gentrifying tracts had higher rates of cycling infrastructure relative to advantaged tracts, and advantaged tracts had higher rates of cycling infrastructure relative to non-gentrifying tracts. In medium-sized cities, gentrifying tracts also had the highest rates of cycling infrastructure, but non-gentrifying tracts had higher rates of infrastructure than advantaged tracts.

Appendix D visualizes the percent difference when comparing the level of cycling infrastructure in gentrifying tracts to not gentrifying or advantaged tracts. These were calculated

by taking the difference in infrastructure rates in gentrifying and the other tract type of tract and dividing by the level of infrastructure in the gentrifying tract. Both charts' bars are colored by the city size. Numbers close to 1 indicate that gentrifying tracts had substantially higher levels of cycling infrastructure relative to the other group. Numbers close to 0 indicate relative equivalence between the two groups, and negative numbers indicate that the tract type to which gentrifying tracts were compared had higher rates of cycling infrastructure in that city. In both charts, the two extreme negative values come from Hartford, CT and Miami, FL. According to the data collected I collected, Hartford lacked cycling infrastructure in gentrifying tracts entirely, and Miami had extremely low levels of cycling infrastructure in gentrifying tracts. More broadly, however, in both charts, the wide range of values suggested that cities were relatively heterogeneous in relative cycling infrastructure allocation among the three tract types. From the comparison between gentrifying and advantaged tracts, medium cities tended to have higher levels of cycling infrastructure relative to large and extremely large cities, but this trend was not as readily apparent in the other chart.

Figure 8: Average Level of Cycling Infrastructure by City Size

Average Cycling Infrastructure by City Size
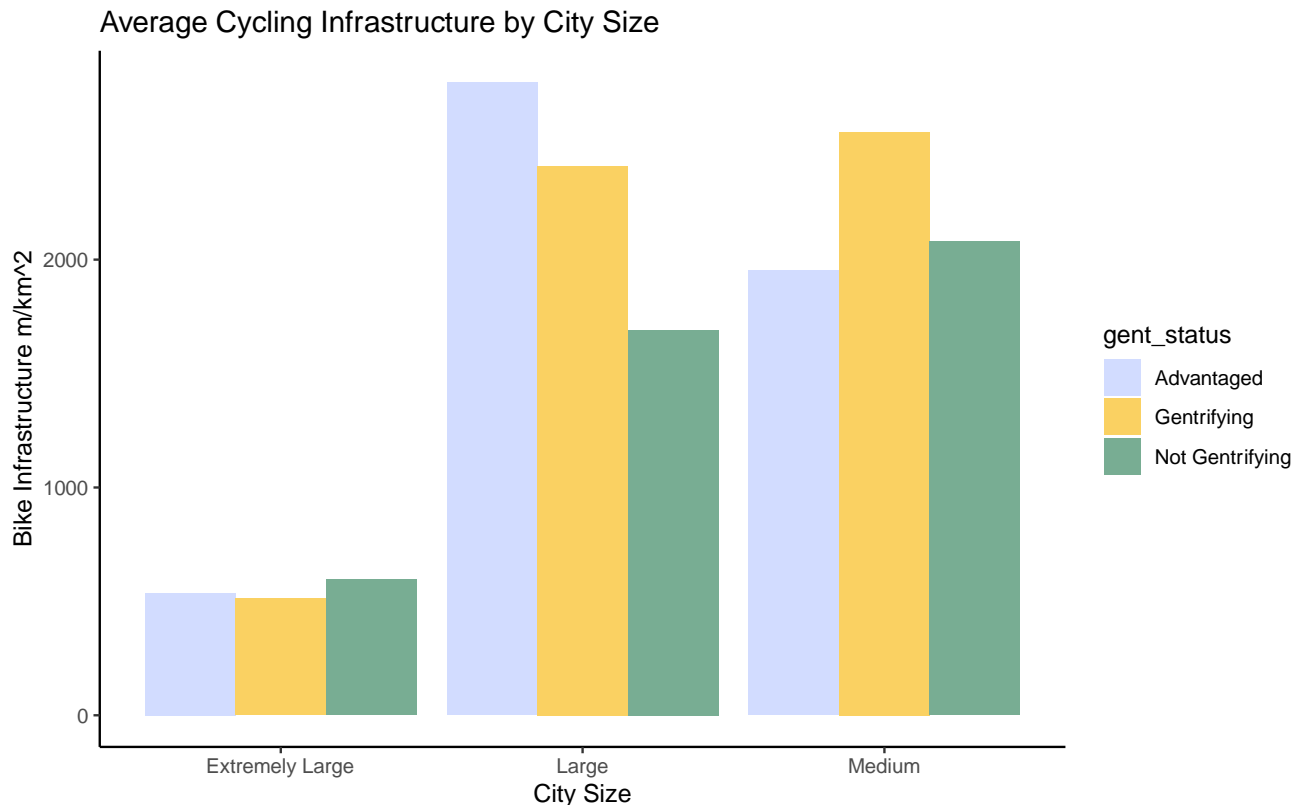
Regression Analysis:

The "full model" described above (see Table 2) used data from all cities. As noted above, the unit of analysis was the census tract, and the dependent variable was meters of bicycle infrastructure per square kilometer. The predictor variables are the Euclidian distance from the centroid of the census tract to the city's CBD, the population density, total population ages 18-34 as of 2019, the total minority population in 2019, a dummy variable for each city, and two dummy variables indicating whether the tract was advantaged, not gentrifying, or gentrifying. The last two dummy variables serve as the independent variables while the other variables controlled for urban form-related factors that external to gentrification could predict cycling infrastructure. Note that due to this specification, gentrification was the baseline to which non-gentrifying and advantaged tracts were compared. I also ran similar models considering each city by region (Table 6) and by city size (Table 7).

Table 2: Full Model Regression Results [5]

	total_lane_rate
is_not_gentrifying	-131.187** (56.534)
is_advantaged	-79.569 (55.548)
dist_to_cbd_km	-42.673*** (2.461)
pop_density	0.006*** (0.002)
pop_18_34_2019	0.400*** (0.023)
minority_2019	-0.169*** (0.011)
Constant	935.806*** (143.537)
N	10,882
R^2	0.665
Adjusted R^2	0.663
Residual Std. Error	1,447.188 (df = 10830)
F Statistic	420.974*** (df = 51; 10830)

Note: $^{***}p < .01$; $^{**}p < .05$; $^{*}p < .1$

The results demonstrated that gentrifying tracts have statistically significantly ($p<.05$) higher rates of bicycle infrastructure relative to non-gentrifying tracts and that the control

---

[5] Note that the dummy variables for each individual city are not included both because including 45 additional rows would be impractical and because their results are not meaningful in this context. They simply compare Atlanta to each other city.

variables were all meaningful predictors of cycling infrastructure. Specifically, when controlling for the other factors in the model, on average gentrifying tracts had about 131 m/km^2 more cycling infrastructure than non-gentrifying tracts. The difference between gentrifying and advantaged tracts was not statistically significant. Each of the predictors were strongly statistically significant (p<.01). For each Euclidian kilometer increase in distance between a census tract's centroid and the city's CBD, there was on average a decrease in around 43 m/km^2 of cycling infrastructure. On average, for each increase in 1000 people per square kilometer, there was an increase of about 6 meters of bicycle infrastructure per square kilometer. Finally, on average, for each increase in population age 18-34 or in minority population, there was an increase of .4 m/km^2 and decrease of about .17 m/km^2 of cycling infrastructure, respectively. In other words, when controlling for many factors, there appeared to be higher rates of cycling infrastructure in gentrifying as opposed to non-gentrifying tracts but no difference between gentrifying and advantaged tracts. Moreover, the control variables were all statistically significant with signs of the expected directions: proximity to the CBD, population density, and young residents all predicted higher cycling infrastructure while minority residents were associated with lower rates of cycling infrastructure. That said, the size coefficients for young residents and minority residents were quite small.

Models for medium and large-sized cities had somewhat distinct results to the overall model. For both medium and large-sized cities, advantaged tracts had strongly statistically significantly higher rates of cycling infrastructure relative to gentrifying tracts, but the difference between gentrifying and non-gentrifying tracts was not statistically significant. All control variables for medium and large-sized cities were statistically significant with the exception of population ages 18-34 in medium cities. All of the signs reflected those of the full model.

Extremely large cities had similar results as the overall model. When controlling for the other variables, they had statistically significant differences between non-gentrifying and gentrifying tracts but not a statistically significant difference between gentrifying and advantaged tracts. Three of the four control variables behaved in the same way as those of the full model, but increasing population density was associated with lower levels of bicycle infrastructure.

Table 3: Regression Results by City Size

	total_lane_rate

	Medium	Large	Extremely Large
is_not_gentrifying	254.932 (169.437)	-50.939 (155.064)	137.578* (77.795)
is_advantaged	361.072** (171.080)	748.356*** (153.313)	24.952 (74.150)
dist_to_cbd_km	-98.492*** (10.434)	-88.620*** (8.068)	-11.226*** (2.233)
pop_density	0.602*** (0.030)	0.153*** (0.009)	-0.018*** (0.001)
pop_18_34_2019	-0.017 (0.076)	0.371*** (0.057)	0.409*** (0.028)
minority_2019	-0.269*** (0.036)	-0.162*** (0.030)	-0.103*** (0.011)
Constant	1,813.829*** (188.579)	1,780.332*** (170.270)	700.285*** (81.922)
N	3,859	2,415	4,608
R^2	0.176	0.273	0.078
Adjusted R^2	0.175	0.271	0.077
Residual Std. Error	2,923.187 (df = 3852)	2,148.448 (df = 2408)	1,068.393 (df = 4601)
F Statistic	137.123*** (df = 6; 3852)	150.938*** (df = 6; 2408)	64.733*** (df = 6; 4601)

Note: ***p < .01; **p < .05; *p < .1

The control variables for each city group followed the same pattern as described above. Higher numbers of minority residents in 2019 predicted lower rates of cycling infrastructure. Otherwise, proximity to the CBD, increased population density, and greater number of residents ages 18-34 in 2019 all predicted increased rates of cycling infrastructure. The only exception was that the population density variable was not statistically significant for cities in the Midwest. All else equal, gentrifying tracts in cities in the Interior West and South had statistically significant and higher rates of cycling infrastructure relative to non-gentrifying tracts. Cities on the West Coast and in the Midwest had no statistically significant (p<.05) difference in gentrifying, non-gentrifying, and advantaged tracts when controlling for the other factors. In the Midwest, there was a marginally statistically significant (p<.10) result that, all else equal, non-gentrifying tracts had *higher* rates of infrastructure relative to gentrifying tracts. Finally, in the Northeast, advantaged tracts had statistically significantly lower rates of cycling infrastructure on average and holding all else equal relative to gentrifying tracts.

Table 4: Regression Results by Region

			total_lane_rate		
	Midwest	West Coast	Interior West	South	Northeast
is_not_gentrifying	587.657*	-269.506	-240.031***	-340.636***	-115.308

	(301.589)	(232.862)	(90.193)	(122.659)	(114.362)
is_advantaged	393.601	-81.034	-108.683	26.826	-481.881***
	(300.746)	(219.641)	(92.124)	(126.352)	(105.769)
dist_to_cbd_km	-225.943***	-56.482***	-47.085***	-99.839***	-112.738***
	(15.706)	(5.185)	(4.105)	(7.450)	(4.995)
pop_density	0.010	0.071***	0.118***	0.159***	-0.046***
	(0.011)	(0.009)	(0.016)	(0.019)	(0.002)
pop_18_34_2019	0.218**	0.541***	0.279***	0.178***	0.660***
	(0.110)	(0.068)	(0.045)	(0.054)	(0.047)
minority_2019	-0.164**	-0.230***	-0.179***	-0.096***	-0.088***
	(0.065)	(0.034)	(0.018)	(0.028)	(0.019)
Constant	3,993.298***	2,411.753***	1,548.467***	1,803.379***	2,592.321***
	(311.236)	(236.284)	(96.142)	(127.167)	(122.576)
N	2,493	1,948	1,705	1,546	3,190
R^2	0.098	0.160	0.205	0.229	0.298
Adjusted R^2	0.096	0.158	0.203	0.226	0.297
Residual Std. Error	3,576.815 (df = 2486)	2,148.304 (df = 1941)	1,010.733 (df = 1698)	1,397.991 (df = 1539)	1,537.046 (df = 3183)
F Statistic	44.871*** (df = 6; 2486)	61.716*** (df = 6; 1941)	73.177*** (df = 6; 1698)	76.128*** (df = 6; 1539)	225.642*** (df = 6; 3183)

Note: ***$p < .01$; **$p < .05$; *$p < .1$

Chapter 6

Discussion

On the whole, the results suggested that there was a substantial difference in bicycle infrastructure in gentrifying, advantaged, and not gentrifying census tracts in major American cities. Overall, gentrifying tracts tended to have greater levels of cycling infrastructure than both advantaged and not gentrifying tracts. When controlling for population density, young residents, minority residents, and distance to the CBD, gentrifying tracts still had, on average, higher levels of cycling infrastructure relative to non-gentrifying tracts. However, the differences between gentrifying and advantaged tracts became statistically insignificant. There was also substantial heterogeneity by city size and region.

One potential explanation for the discrepancies between the statistical tests was that gentrifying tracts and bicycle infrastructure tended to be closer to the CBD. Specifically, on average, gentrifying tracts were 6.8 km from the CBD whereas non-gentrifying and advantaged tracts were 9.5 km and 11.7 km from the CBD, respectively (see Appendix F). Additionally, the academic literature (Braun, 2018; Flanagan et al., 2016; Houde et al., 2018) recognized the association between proximity to the CBD and higher rates of cycling infrastructure, a conclusion I also reached. Specifically, in a univariate regression, the two were strongly negatively associated ($p < .01$), meaning that as the distance from the CBD grew, the model predicted less bicycle infrastructure (see Appendix F). Given these relationships, it was not surprising that, when accounting for a variable like proximity to the CBD, the significance of the difference between groups shrank. This was an important finding because it suggested that city residents living far from the CBD tended to lack the same level of access to cycling infrastructure when accounting for other factors.

Results on the covariates generally aligned with the findings of previous literature. Specifically, this thesis reaffirmed the findings of Braun (2018), Flanagan et al. (2016), and Hirsch et al. (2017) that proximity to the CBD, population density, and population of young residents were all strong predictors of cycling infrastructure. This finding supported the notion that cycling infrastructure is allocated, at least in part, based on urban form and demographic characteristics that suggested a region was conducive to high levels of cycling.

This thesis's findings that overall, across cities of all sizes, and in cities of all regions, minority resident presence had negative associations with cycling infrastructure were generally supported by the literature. Braun (2018) found that the increased presence of Hispanic residents had negative associations with bicycle infrastructure. Flanagan et al. (2016) concluded that tracts that were more than 40% non-White tended to have less cycling infrastructure investment in Chicago. More broadly, Braun (2018), Flanagan et al. (2016), and Tucker & Manaugh (2018) all reached similar conclusions that disadvantaged regions, admittedly defined uniquely in each paper, had relatively less cyling infrastructure even when controlling for the above factors. Also, in the American context, Braun (2018) used data from 2000 as well as 2011-2015, and Flanagan et al. (2016) utilized data from 1990 – 2010. As noted above, this thesis used demographic data from 2015-2019 and cycling data from 2015-2020, suggesting that the relative inequity of cycling infrastructure has persisted at least through the 2010s in the United States. Notably, this finding contrasted with Montreal and two surrounding cities where disadvantaged residents had good access to the cycling network, in part because space was available in those areas after they experienced industrial decline (Houde et al. 2018).

By studying 46 cities, this thesis suggested that there was substantial spatial heterogeneity in the allocation of cycling infrastructure by tract gentrification status at the city scale. Specifically, I found that when controlling for the urban form covariates, cities in the South and Interior West drove the overall trend between gentrifying and non-gentrifying tracts' cycling infrastructure. However, the Northeast showed an entirely distinct relationship with advantaged tracts having *lower* levels of cycling infrastructure relative to gentrifying tracts. Using $p<.05$, the Midwest and the West Coast showed no statistically significant difference between gentrifying tracts and the other two types. This result expanded Braun's (2018) finding of substantive variation in associations between cycling infrastructure and demographic advantage in Oakland, Chicago, and Minneapolis, suggesting that there existed different patternings of cycling infrastructure across many cities in the United States. This finding was also supported by the percent difference charts shown in Appendix D.

When analyzing associations by size, this thesis's research conflicted with some of Braun's (2018) findings. In her cross-sectional analysis of 22 cities, she regressed a measure of cycling infrastructure on measures of sociodemographic characteristics (race, ethnicity, education, income, and poverty) while controlling for similar covariates; admittedly, in this

section of her disertation she did not specifically consider gentrification. She found that percent Hispanic, and poverty level negatively correlate with cycling infrastructure density and reach, and education level and income level had positive associations with the same measures. She conducted the same analysis exclusively considering the three largest American cities, New York, Los Angeles, and Chicago, and separately assessing the other 19 in her study. She generally found the magnitude of the coefficients in her regression to be larger in the largest three cities, leading to some results in the remaining 19 cities losing significance. This thesis contrasted with that finding. Whereas, when controlling for other factors, gentrifying tracts had higher levels of cycling infrastructure in medium and large cities, extremely large cities had about the same levels of cycling infrastructure in each of the three types of tracts. Thus, this finding contrasted with Braun (2018) because I found that socioeconomic privelege, in this case determined by tract gentrifiction status, and cycling infrastructure was less pronouned in the largest cities, whereas she found it to be more pronounced.

   This thesis's findings could be consistent with, but ultimately are unable to support, claims that bicycle lanes cause gentrification. This study relied on cross-sectional, observational data and made no effort to conduct a natural experiment. Consequently, it cannot claim causality between cycling lane development and gentrification. Even so, it did find strong evidence of an association between gentrifying census tracts in major American cities and increased cycling infrastructure. This could be consistent with a dynamic where regions first develop cycling infrastructure which subsequently causes the surrounding region to gentrify or a model in which regions develop cycling infrastructure while gentrifying simultaneously. As noted in the literature review, Braun (2018) found that cycling infrastructure followed gentrification in Chicago and co-occurred with gentrification in Oakland. This thesis's findings cannot distinguish between these temporal dynamics specifically because they were cross-sectional; the findings represented a snapshot of the association between gentrification defined by demographic characteristics collected between 2015 and 2019 and cycling lane infrastructure data at some point between 2015 and 2020.

   The findings presented in this thesis likely add little support to the contention pushed by some politicians and community advocates that cycling lane development causes displacement, but they do not reject this claim either. As described in the Literature Review, some politicians and community members have argued that cycling infrastructure development caused

gentrifiction (O'Sullivan, 2021; Kramer, 2020), and, generally, gentrification is considered to be a cause of displcement (Shaw, 2008). In other words, there appears to be a conception that cycling lane development, at least in some areas, causes gentrification, and gentrifiction subsequently causes displacement. My inability to make causal claims means this thesis cannot support the first causal claim (cycling infrstructure development causes gentrification), but, again, it strongly supports the notion that they are associated. Again, as noted in the Literature Review, academic literature has suggested that gentrification may not necessarily cause displacement in all cases (Hennig, 1980; Vigdor 2002; Freeman and Braconi, 2004; Dragan et al., 2019), and when it does, its effects can be relatively small in magnitude (Newman and Wyly, 2006; Brummet and Reed, 2019; Owen, 2019) or located in a handful of very large cities (Freeman et al., 2016). Thus, the research presented here cannot support the conception that cycling infrastructure development causes displacement. That being said, I found no evidence to further dispute this conception beyond the previously published studies on gentrification. In short, the question of whether cycling infrastructure development causes gentrification is beyond the scope of this thesis.

Finally, my findings suggested that more tension around bicycle infrastructure development could occur in the future. Notably, Hoffman (2016) and Lubitow et al. (2016) described how the development of cycling infrastructure in minority communities undergoing or fearful of gentrification caused major frustration among long-time residents of those areas. I found that, even when controlling for a number of other factors, higher numbers of minority residents and a tract being classified as not gentrifying predicted decreased levels of cycling infrastructure. In other words, my findings suggested that it is common for not gentrifying communities with high numbers of minority residents to lack cycling infrastructure, and Hoffman (2016) and Lubitow et al. (2016) higlight a pattern of residents of these areas becoming frustrated with investments in cycling infrastructure. Thus, it seems likely that if city agencies continue to have similarly poor community engagement and dialogue before building their bike lanes in historically marginalized communities, similar tensions could continue to occur.

Limitations

This study is not without its limitations. First, as noted above, I was unable to make any claims about causality. Additionally, the lack of temporal data meant I could not make any

claims about whether bike lanes preceded or followed gentrification. Computationally, my selection of census tracts was not without flaw. The method I used occassionally missed census tracts, particularly when they were at the edge of cities and were abnormally shaped. As noted in the methods section, I also did not use data from eight cities with more than a million residents in their MSAs. Consequently, despite the fact the sample size in this study was large, overstating the level of cycling infrasturcture is quite possible. Specifically, it seems probable that there is a correlation between cities having publically available or requestable cycling lane spatial data and their level of cycling infrastructure overall, so my sample of cities could overestimate the level of cycling infrastructure in *all* 55 cities with MSAs of a million people or more. As noted when discussing the cycling lane data, classification schemes were heterogeneous and often missing across different cities' datasets, so the classifiction presented in Figure 6 should be viewed as an educated estimate rather than a precise calculation of all cities' cycling infrastructure. It is also certainly up for debate whether sharrows and more generally shared lanes truly constitute cycling infrastructure. I considered them here, but they are obviously less safe and useful for cyclists relative to other, more protected forms of cycling infrastructure.

Future Work

Quantitative work focusing on the causal relationships between bicycle infrastructure development and gentrification and continued focus of qualitative research on the impacts of bicycle infrastructure are needed. First, as noted above, this research follows a number of other quantitative bike infrastructure and socio-economic advantage/gentrification asssessments, none of which make conclusive causal claims, even though the idea of the causal relationship is common among the public and in the media. Thus, that is an important direction for future work. Second, more work could be done specifically comparing the spatial patterning of cycling infrastructure in extremely large cities relative to smaller ones. This thesis identified how those cities had different dynamics than smallers cities but does not consider why this was the case. Qualitative literature on the interactions between bicycle infrastructure development and gentrification is also necessary. Among others, Hoffmann (2016) and Lubitow et al. (2016) provided outstanding ethnographies on the topic. However, the field has continued to be discussed in the media in a pandemic context (Badger, 2020) as well as more generally in urban

politics, policy, and planning circles (O'Sullivan, 2021; Kramer, 2020). Current research has only considered a handful of neighborhoods in a few cities.

Chapter 7

Conclusion

This thesis sought to assess the quantitative associations between gentrification and bicycle infrastructure in 46 central cities in the United States. When controlling for population density, proximity to the CBD, number of young residents (ages 18-34) and number of minority residents, it found that in the cities studied, gentrifying tracts tended to have higher rates of cycling infrastructure relative to non-gentrifying tracts. It also found that minority residents were negatively associated with cycling infrastructure across all city sizes and in all regions of the US. These conclusions were noteworthy because they supported previous literature that had used earlier data while substantially broadening the breadth of the findings and because they highlighted clear inequity in urban resources that are particularly harmful to underprivileged residents (i.e. minorities and those living in non-gentrifying, non-advantage areas). By considering cities by region and population size, it concluded that the difference between gentrifying and non-gentrifying tracts was driven by cities in the South and Interior West and that there was substantial heterogeneity in both cites' level of cycling infrastructure when considering tract gentrification status. It also found that advantaged tracts in the Northeast had lower rates of cycling infrastructure compared with gentrifying tracts. While it could not support popular claims about the *causal* relationship between bicycle infrastructure and gentrification and displacement, it did find clear evidence of inequity at the expense of minority residents and those living in non-gentrifying tracts.

Bibliography

Atkinson, R., & Easthope, H. (2009). The Consequences of the Creative Class: The Pursuit of Creativity Strategies in Australia's Cities. *International Journal of Urban and Regional Research*, *33*(1), 64–79. https://doi.org/10.1111/j.1468-2427.2009.00837.x

Badger, E. (2020, July 20). The Pandemic Has Pushed Aside City Planning Rules. But to Whose Benefit? *The New York Times*. https://www.nytimes.com/2020/07/20/upshot/pandemic-city-planning-inequality.html

Billingham, C. M. (2017). Waiting for Bobos: Displacement and Impeded Gentrification in a Midwestern City: DISPLACEMENT AND IMPEDED GENTRIFICATION. *City & Community*, *16*(2), 145–168. https://doi.org/10.1111/cico.12235

Bohl, C. C. (2000). New urbanism and the city: Potential applications and implications for distressed inner-city neighborhoods. *Housing Policy Debate*, *11*(4), 761–801. https://doi.org/10.1080/10511482.2000.9521387

Braun, Lindsay Maurer. (2018). *GEOGRAPHIES OF (DIS)ADVANTAGE IN WALKING AND CYCLING: PERSPECTIVES ON EQUITY AND SOCIAL JUSTICE IN PLANNING FOR ACTIVE TRANSPORTATION IN U.S. CITIES*. University of North Carolina at Chapel Hill.

Chetty, R., Hendren, N., & Katz, L. F. (2016). The Effects of Exposure to Better Neighborhoods on Children: New Evidence from the Moving to Opportunity Experiment. *American Economic Review*, *106*(4), 855–902. https://doi.org/10.1257/aer.20150572

Congress for the New Urbanism. (2000). Charter of the New Urbanism. *Bulletin of Science, Technology & Society*, *20*(4), 339–341. https://doi.org/10.1177/027046760002000417

Cortwright, J., & Mahmoudi, D. (2014). *Lost in Place:* City Observatory.

https://cityobservatory.org/wp-content/uploads/2014/12/LostinPlace_12.4.pdf

Davis, P. (2011, August 30). Are Bike Lanes Expressways to Gentrification? *Shareable*.

https://www.shareable.net/are-bike-lanes-expressways-to-gentrification/

Day, K. (2003). New Urbanism and the Challenges of Designing for Diversity. *Journal of*

Planning Education and Research, *23*(1), 83–95.

https://doi.org/10.1177/0739456X03255424

Dragan, K., Ellen, I. G., & Glied, S. (2020). Does gentrification displace poor children and their

families? New evidence from medicaid data in New York City. *Regional Science and*

Urban Economics, *83*, 103481. https://doi.org/10.1016/j.regsciurbeco.2019.103481

Elliott-Cooper, A., Hubbard, P., & Lees, L. (2020). Moving beyond Marcuse: Gentrification,

displacement and the violence of un-homing. *Progress in Human Geography*, *44*(3),

492–509. https://doi.org/10.1177/0309132519830511

Fee, K., & Hartley, D. (2012). *The relationship between city center density and urban growth or*

decline (Working Papers (Old Series) No. 1213). Federal Reserve Bank of Cleveland.

https://econpapers.repec.org/paper/fipfedcwp/1213.htm

Flanagan, E., Lachapelle, U., & El-Geneidy, A. (2016). Riding tandem: Does cycling

infrastructure investment mirror gentrification and privilege in Portland, OR and

Chicago, IL? *Research in Transportation Economics*, *60*, 14–24.

https://doi.org/10.1016/j.retrec.2016.07.027

Florida, R. (2002). *The Rise of the Creative Class*. Basic Books.

Folch, D. C., Arribas-Bel, D., Koschinsky, J., & Spielman, S. E. (2014). Spatial Variation in the

    Quality of American Community Survey Estimates. *Demography*, *53*(5), 1535–1554.

    https://doi.org/10.1007/s13524-016-0499-1

Freeman, L. (2005). Displacement or succession? Residential mobility in gentrifying

    neighborhoods. *Urban Affairs Review*, *40*(4), 463–491.

Freeman, L. (2006). *There Goes the Hood: Views of Gentrification from the Ground Up*. Temple

    University Press.

Freeman, L., & Braconi, F. (2004). Gentrification and displacement New York City in the 1990s.

    Journal of the American Planning Association, *70*(1), 39–52.

Freeman, L., Cassola, A., & Cai, T. (2016). Displacement and gentrification in England and

    Wales: A quasi-experimental approach. *Urban Studies*, *53*(13), 2797–2814.

    https://doi.org/10.1177/0042098015598120

Glaeser, E. L. (n.d.). *Review of Richard Florida's The Rise of the Creative Class*. 5.

Goodyear, S. (2011, September 20). Bike Lane Backlash, Even in Portland. *Bloomberg.Com*.

    https://www.bloomberg.com/news/articles/2011-09-20/bike-lane-backlash-even-in-

    portland

goray. (2016, July 21). *GIS Files* [Text]. IPUMS NHGIS.

    https://www.nhgis.org/documentation/gis-data

Grant, J. (2011). Time, Scale, and Control: How New Urbanism (Mis)uses Jane Jacobs. In

    Reconsidering Jane Jacobs (pp. 91–177). American Planning Association Planners Press.

Henig, J. R. (1980). *GENTRIFICATION AND DISPLACEMENT WITHIN CITIES: A*

    COMPARATIVE ANALYSIS. *Social Science Quarterly*. 16(3/4) pp. 638-652.

Hirsch, J. A., Green, G. F., Peterson, M., Rodriguez, D. A., & Gordon-Larsen, P. (2017).

    Neighborhood sociodemographics and change in built infrastructure. *Journal of*

    Urbanism: International Research on Placemaking and Urban Sustainability, *10*(2),

    181–197. https://doi.org/10.1080/17549175.2016.1212914

Hoffmann, M. L. (2016). *Bike Lanes Are White Lanes: Bicycle Advocacy and Urban Planning*.

    UNP - Nebraska.

    http://ebookcentral.proquest.com/lib/uchicago/detail.action?docID=4529739

Holian, M. J. (2019). Where Is the City's Center? Five Measures of Central Location. *Cityscape:*

    A Journal of Policy Development and Research, *21*(2), 213–225.

Houde, M., Apparicio, P., & Séguin, A.-M. (2018). A ride for whom: Has cycling network

    expansion reduced inequities in accessibility in Montreal, Canada? *Journal of Transport*

    Geography, *68*, 9–21. https://doi.org/10.1016/j.jtrangeo.2018.02.005

Kramer, J. (2020, August 18). *Do D.C.'s Slow Streets Benefit Everyone?* Washington City Paper.

    https://washingtoncitypaper.com/article/303481/do-dcs-slow-streets-benefit-everyone/

Larsen, K. (2005). New Urbanism's Role in Inner-city Neighborhood Revitalization. *Housing*

    Studies, *20*(5), 795–813. https://doi.org/10.1080/02673030500214068

Lepeska, D. (2011, October 15). City Bike Plan Is Accused of a Neighborhood Bias. *The New*

    York Times. https://www.nytimes.com/2011/10/16/us/chicago-bike-plan-accused-of-

    neighborhood-bias.html

Lubitow, A., Zinschlag, B., & Rochester, N. (2016). Plans for pavement or for people? The

    politics of bike lanes on the 'Paseo Boricua'in Chicago, Illinois. *Urban Studies*, *53*(12),

    2637–2653.

McLeod, K., Herpolsheimer, S., Clarke, K., & Woodard, K. (2018). *Bicycling and Walking in the United States 2018 Benchmark Result* (pp. 1–416). League of American Cyclists. https://bikeleague.org/benchmarking-report

Mirk, S. (2012). *It's Not About the Bikes*. Portland Mercury. https://www.portlandmercury.com/portland/its-not-about-the-bikes/Content?oid=5619639

Newman, K., & Wyly, E. K. (2006). The Right to Stay Put, Revisited: Gentrification and Resistance to Displacement in New York City. *Urban Studies*, *43*(1), 23–57. https://doi.org/10.1080/00420980500388710

O'Sullivan, F. (2021, March 2). Where the '15-Minute City' Falls Short. *Bloomberg Citylab*. https://www.bloomberg.com/news/articles/2021-03-02/the-downsides-of-a-15-minute-city?sref=pD2ECzY4

Peck, J. (2005). Struggling with the Creative Class. *International Journal of Urban and Regional Research*, *29*(4), 740–770.

Shaw, K. (2008). Gentrification: What It Is, Why It Is, and What Can Be Done about It. *Geography Compass*, *2*(5), 1697–1728. https://doi.org/10.1111/j.1749-8198.2008.00156.x

Talen, E. (2012). Jane Jacobs and the Diversity Ideal. *The Urban Wisdom of Jane Jacobs*, *c.1*, 212–228.

Tavernise, S. (2011, July 17). A Population Changes, Uneasily. *The New York Times*. https://www.nytimes.com/2011/07/18/us/18dc.html

Tucker, B., & Manaugh, K. (2018). Bicycle equity in Brazil: Access to safe cycling routes across

    neighborhoods in Rio de Janeiro and Curitiba. *International Journal of Sustainable*

    Transportation, *12*(1), 29–38. https://doi.org/10.1080/15568318.2017.1324585

Vigdor, J. L., Massey, D. S., & Rivlin, A. M. (2002). Does gentrification harm the poor?[with

    Comments]. *Brookings-Wharton Papers on Urban Affairs*, 133–182.

Wilson, D., & Keil, R. (2008). The real creative class. *Social & Cultural Geography*, *9*(8), 841–

    847. https://doi.org/10.1080/14649360802441473

Appendix A

City Size and Region Classification

City Name	Region Classification:	Size Classification:
Atlanta	South	Large
Baltimore	Northeast	Medium
Boston	Northeast	Large
Buffalo	Midwest	Medium
Charlotte	South	Medium
Chicago	Midwest	Extremely Large
Cleveland	Midwest	Medium
Columbus	Midwest	Medium
Dallas	Interior West	Extremely Large
Denver	Interior West	Medium
Detroit	Midwest	Large
Fort Worth	Interior West	Medium
Houston	Interior West	Extremely Large
Indianapolis	Midwest	Medium
Jacksonville	South	Medium
Kansas City	Midwest	Medium
Las Vegas	Interior West	Medium
Los Angeles	West Coast	Extremely Large
Louisville	South	Medium
Memphis	South	Medium
Miami	South	Large
Milwaukee	Midwest	Medium
Minneapolis	Midwest	Large
Nashville	South	Medium
New Orleans	South	Medium
New York	Northeast	Extremely Large

Oklahoma City	South	Medium
Orlando	South	Medium
Philadelphia	Northeast	Large
Phoenix	Interior West	Large
Pittsburgh	Midwest	Medium
Portland	West Coast	Medium
Providence	Northeast	Medium
Raleigh	South	Medium
Sacramento	West Coast	Medium
Salt Lake City	Interior West	Medium
San Antonio	Interior West	Medium
San Diego	West Coast	Large
San Francisco	West Coast	Large
San Jose	West Coast	Medium
Seattle	West Coast	Large
St. Louis	Midwest	Medium
St. Paul	Midwest	Large
Tampa	South	Large
Virginia Beach	Northeast	Medium
Washington	Northeast	Large

Gentrifying Tracts by City

City Name	Count Advantaged	Count Gentrifying	Count Not Gentrifying
Atlanta	38	15	60
Baltimore	42	16	136
Boston	131	12	26
Buffalo	42	14	23
Charlotte	65	17	66
Chicago	346	27	416
Cleveland	194	12	146
Columbus	78	36	214
Dallas	101	24	150
Denver	44	35	58
Detroit	74	6	213
Fort Worth	38	1	78
Houston	144	29	242
Indianapolis	73	19	131
Jacksonville	120	2	188
Kansas City	41	11	81
Las Vegas	53	4	63
Los Angeles	769	22	192
Louisville	105	8	77
Memphis	43	8	101
Miami	32	7	49
Milwaukee	72	7	130
Minneapolis	30	13	69
Nashville	63	27	64
New Orleans	81	41	50

New York	1639	102	384
Oklahoma City	93	10	95
Orlando	10	1	15
Philadelphia	162	36	183
Phoenix	121	31	168
Pittsburgh	73	13	26
Portland	92	54	118
Providence	27	NA	8
Raleigh	15	6	23
Sacramento	34	11	43
Salt Lake City	16	13	17
San Antonio	98	18	143
San Diego	163	16	87
San Francisco	158	7	30
San Jose	120	5	32
Seattle	75	12	33
St. Louis	34	14	58
St. Paul	13	6	62
Tampa	43	5	31
Virginia Beach	83	1	13
Washington	57	60	60

Bicycle Infrastructure Levels and Significance of Differences

Average Bicycle Infrastructure (m/km^2) by Tract Gentrification Status All Cities

Lane Type:	Advantaged	Gentrifying	Not Gentrifying	p value Ad. v Gent.	p value Ad. v Not Gent.	p value Gent. v Not Gent.
Total Lane	1367.0	1983.8	1508.2	0.000	0.017	0.000
Separated Trail/Path	170.7	253.6	170.0	0.001	1.000	0.002
Protected Lane	43.5	53.0	25.4	1.000	0.001	0.011
Painted Lane	584.8	758.5	559.8	0.000	0.694	0.000
Bike Boulevard	30.2	153.8	43.9	0.000	0.031	0.000
Shared Lane	384.0	619.5	345.2	0.000	0.13	0.000

Average Bicycle Infrastructure (m/km^2) by Gentrification Status and City Location

US Region	Advantaged	Gentrifying	Not Gentrifying	p value Ad. v Gent.	p value Ad. v Not Gent.	p value Gent. v Not Gent.
Interior West	964.1	1620.3	839.7	0.000	0.028	0.000
Midwest	2509.6	2773.6	2301.9	0.39	0.39	0.27
Northeast	652.0	1528.2	1087.4	0.000	0.000	0.0055
South	1075.1	1738.6	929.9	0.000	0.091	0.000
West Coast	2026.6	2723.5	2080.2	0.023	0.643	0.034

Average Bicycle Infrastructure (m/square km by Tract Gentrification Status and City Size

City Size:	Advantaged	Gentrifying	Not Gentrifying	p value Ad. v Gent.	p value Ad. v Not Gent.	p value Gent. v Not Gent.
extremely_large	537.0	513.5	596.5	0.76	0.31	0.59
large	2777.9	2412.4	1692.0	0.032	0.000	0.000
medium	1952.7	2560.8	2079.6	0.000	0.253	0.005

Percent Difference Charts

Percent Difference in Advantaged and Gentrifying Cycling Infrastructure
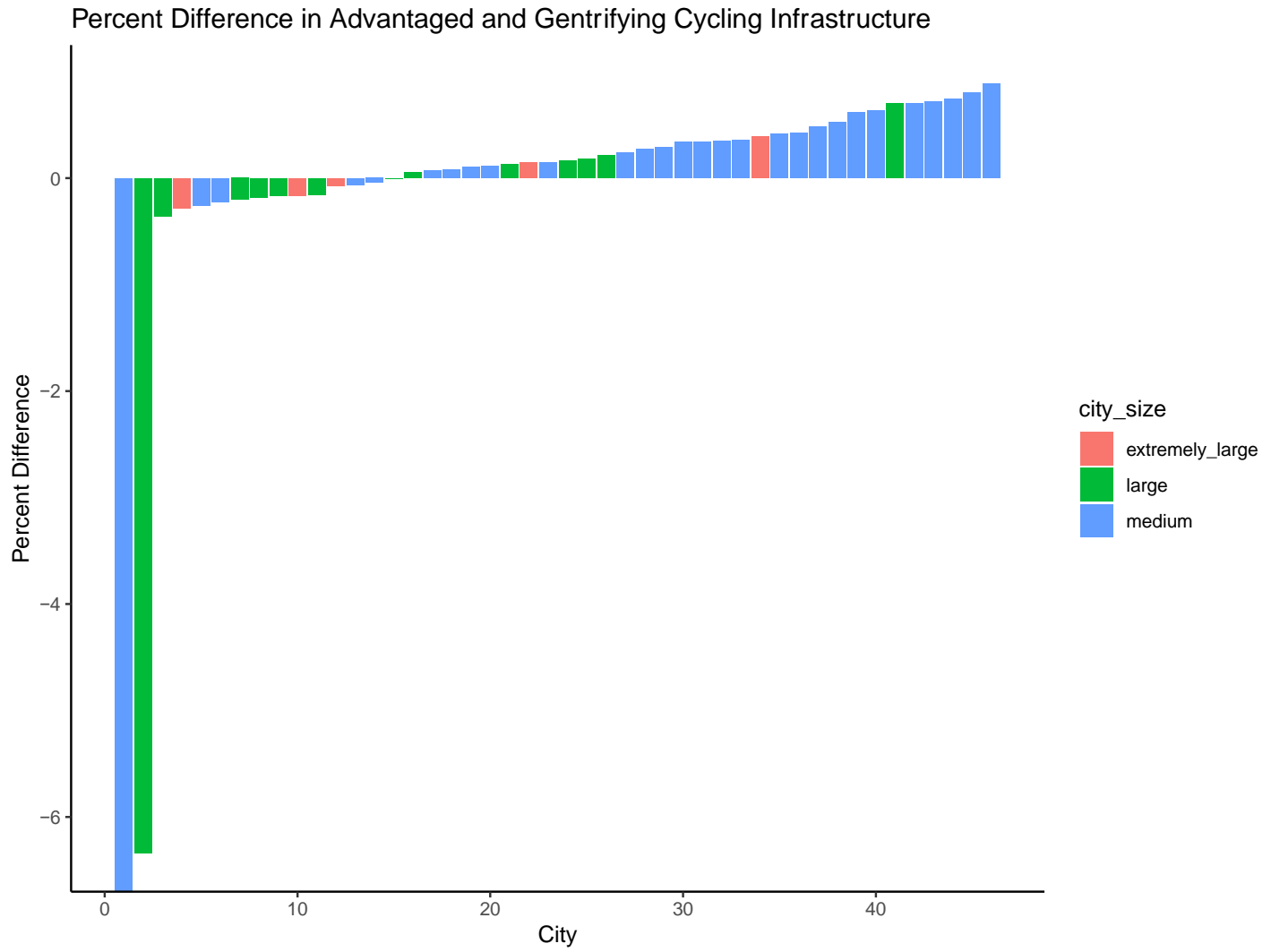
Percent Difference in Disadvantaged and Gentrifying Cycling Infrastructure
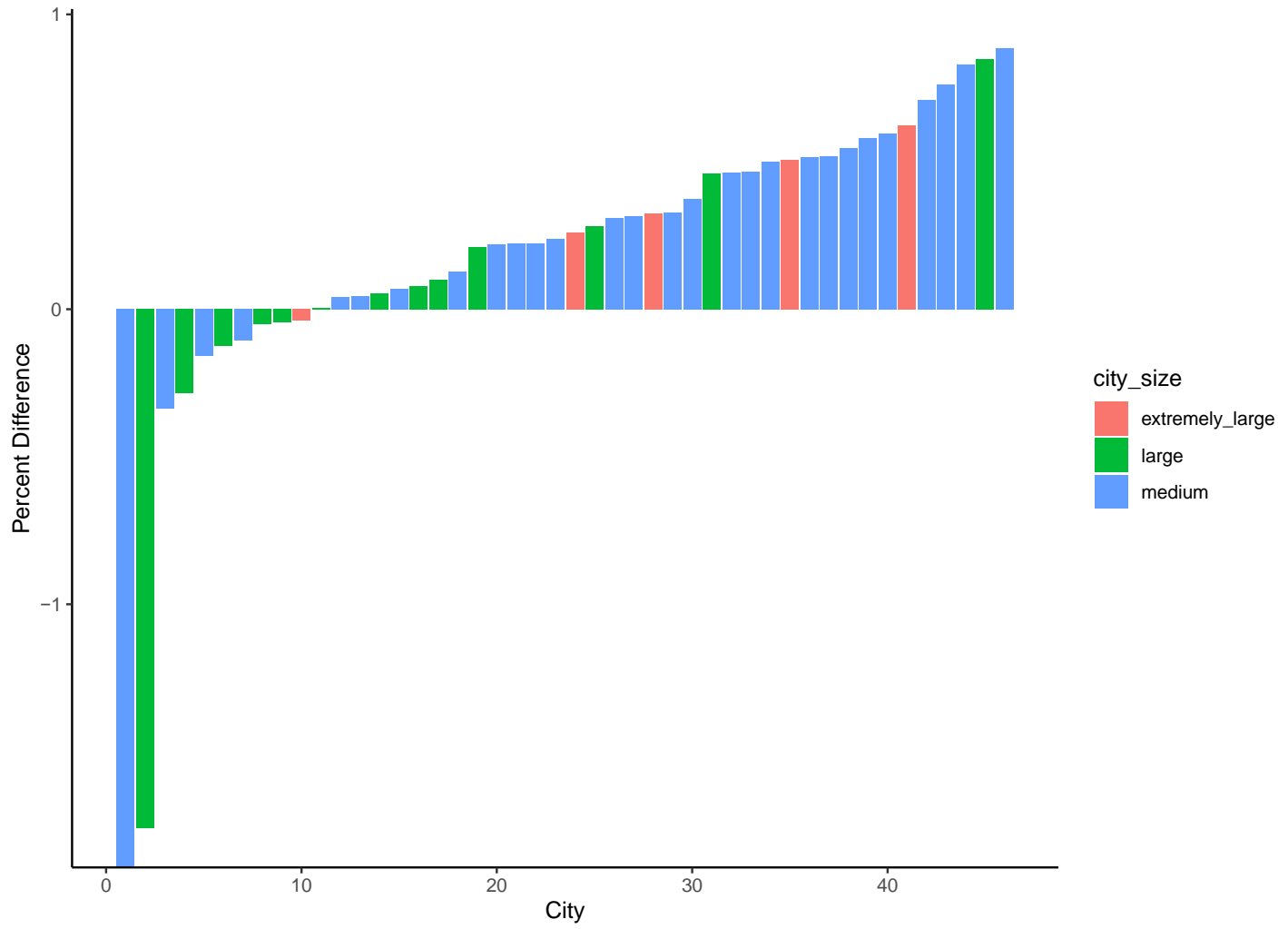
Bicycle Lane Infrastructure by Gentrification Status and City (m/km^2)

Significance levels are intentionally not reported here. Given that I report all census tracts within each of the cities, they constitute the entire population of interest. Therefore, these parameters represent the population parameter.

City	Advantaged	Gentrifying	Not Gentrifying
Atlanta	912.9	1158.7	624.5
Baltimore	2741	2581.3	1248.6
Boston	3364	2905.4	3059.9
Buffalo	1268.8	1919.2	920.5
Charlotte	502.9	1323.9	556.4
Chicago	1572.6	1345.6	996.7
Cleveland	803.6	2692.7	783.4
Columbus	1270	2469.2	1232
Dallas	334.5	313.5	118.4
Denver	2379.1	2647.9	2525.2
Detroit	824	2735.8	412.3
Fort Worth	708.6	3574.9	408.1
Houston	587.6	965.7	477.1
Indianapolis	837.4	1438.2	1120.3
Jacksonville	490.6	1916.5	327.3
Kansas City	1467.1	2247	1710.8
Las Vegas	1748.4	2420.1	1634.1
Los Angeles	1155.2	1363.6	1408

Louisville	402.7	3612.9	861
Memphis	1163.8	1629.3	740
Miami	3670.2	500.4	1375.8
Milwaukee	13190.1	14206	13205.4
Minneapolis	2083.7	1762.8	1976.6
Nashville	767.3	1196.3	827.2
New Orleans	1941	2278.1	1773.3
New York	36.3	28.3	19.1
Oklahoma City	503.7	1793.1	725.4
Orlando	2756.2	2197.9	2943.9
Philadelphia	2591	2216.6	2322.7
Phoenix	1338.8	1606.4	1265.7
Pittsburgh	4173.3	4716.8	2945.5
Portland	2288.1	2478.4	2744.4
Providence	2931.9	NA	2373.8
Raleigh	668.4	1841.6	1256
Sacramento	2989.9	5165.2	2764
Salt Lake City	2348.3	3101	3592.4
San Antonio	517.3	1087.1	584.1
San Diego	1564.5	1651.3	1563.4
San Francisco	5847.4	7173.5	5146.7
San Jose	2420.8	1979.4	1898.7
Seattle	2688.7	2673.6	2663.3
St. Louis	2711.5	2599.9	2272.9
St. Paul	2139.1	2467.3	2222.9

Tampa	2327.3	1941	2489.5
Virginia Beach	491.8	747.4	581.8
Washington	4226.5	3121.8	2874.7

Mean Distance to CBD by Gentrification Status

Tract Type	Mean Distance to CBD (km)
Advantaged	11.7
Gentrifying	6.8
Not Gentrifying	9.5

Univariate Linear Regression: Distance to CBD

	total_lane_rate
dist_to_cbd_km	-105.068[***] (3.330)
Constant	2,562.628[***] (41.576)
N	10,882
R^2	0.084
Adjusted R^2	0.084
Residual Std. Error	2,386.677 (df = 10880)
F Statistic	995.750[***] (df = 1; 10880)
Note:	[***]$p < .01$; [**]$p < .05$; [*]$p < .1$