The Effects of Rail Stations on Neighborhood Displacement in Los Angeles County, 1993-2013

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A Research Report from the Pacific Southwest Region University Transportation Center

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16. Abstract
We examine the effect of rail transit on neighborhood displacement. To do so, we leverage the tax filing records of over 100 million households from Los Angeles County between 1993 and 2013, provided by the California Franchise Tax Board (FTB). We look at the neighborhoods surrounding the 80 L.A. Metro rail stations opened since 1993, calculating these station areas' resident move-out rates for each year within our tax filing dataset. We estimate changes in out-mobility rates in response to station opening for 80 rail stations by examining the change before and after train stations open and against control areas. The use of control areas enhances the robustness of our analysis.

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Contents

About the Pacific Southwest Region University Transportation Center

The Pacific Southwest Region University Transportation Center (UTC) is the Region 9 University Transportation Center funded under the US Department of Transportation's University Transportation Centers Program. Established in 2016, the Pacific Southwest Region UTC (PSR) is led by the University of Southern California and includes seven partners: Long Beach State University; University of California, Davis; University of California, Irvine; University of California, Los Angeles; University of Hawaii; Northern Arizona University; Pima Community College.

The Pacific Southwest Region UTC conducts an integrated, multidisciplinary program of research, education and technology transfer aimed at *improving the mobility of people and goods throughout the region.* Our program is organized around four themes: 1) technology to address transportation problems and improve mobility; 2) improving mobility for vulnerable populations; 3) Improving resilience and protecting the environment; and 4) managing mobility in high growth areas.

U.S. Department of Transportation (USDOT) Disclaimer

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The Effects of Rail Stations on Neighborhood Displacement in Los Angeles County, 1993-2013

Executive Summary

We examine the effect of rail transit on neighborhood displacement. To do so, we leverage the tax filing records of over 100 million households from Los Angeles County between 1993 and 2013, provided by the California Franchise Tax Board (FTB). We look at the neighborhoods surrounding the 80 L.A. Metro rail stations opened since 1993, calculating these station areas' resident move-out rates for each year within our tax filing dataset.

We estimate changes in out-mobility rates in response to station opening for 80 rail stations by examining the change before and after train stations open and against control areas. The use of control areas enhances the robustness of our analysis.

We differentiate estimates of rail transit's effects on station areas' out-mobility rates by:

1. Four income categories of households – < 30% of Area Median Income or AMI (Lowest Income), between 30 to 50% of AMI (Low Income), between 50 and 80% of AMI (Lower-Middle Income), and > 80% of AMI (Middle and Upper Income);[1]
2. Individual rail corridors – Red/Purple, Gold, Blue, Green, and Expo Phase I lines – as well as the entire L.A. Metro rail system; and
3. Three different points in rail stations' development cycle: the announcement of a rail station being developed, the opening of that rail station, and five years after the opening of that station. We interpret statistically significant increases in a particular group's annual out-mobility rate, relative to the control group, to represent displacement.

We hypothesize that the presence of a rail station in a neighborhood displaces low-income residents from that neighborhood. If empirically confirmed, such a phenomenon could present a troubling complication to the potential equity benefits of introducing rail stations to previously "transit-poor" neighborhoods. We rationalize our hypothesis via the following conceptual framework:

1. The introduction of rail stations to neighborhoods results in increased land and housing price values as well as the in-movement of higher-income individuals;
2. This increases competition for station area housing between existing and prospective residents; and

[1] In 2013, Lowest Income is defined as less than $15,000; Low Income is defined as $15,000 - $25,000; Lower-Middle Income is defined as $25,000-$40,000; and Middle and Upper Income is defined as more than $40,000.

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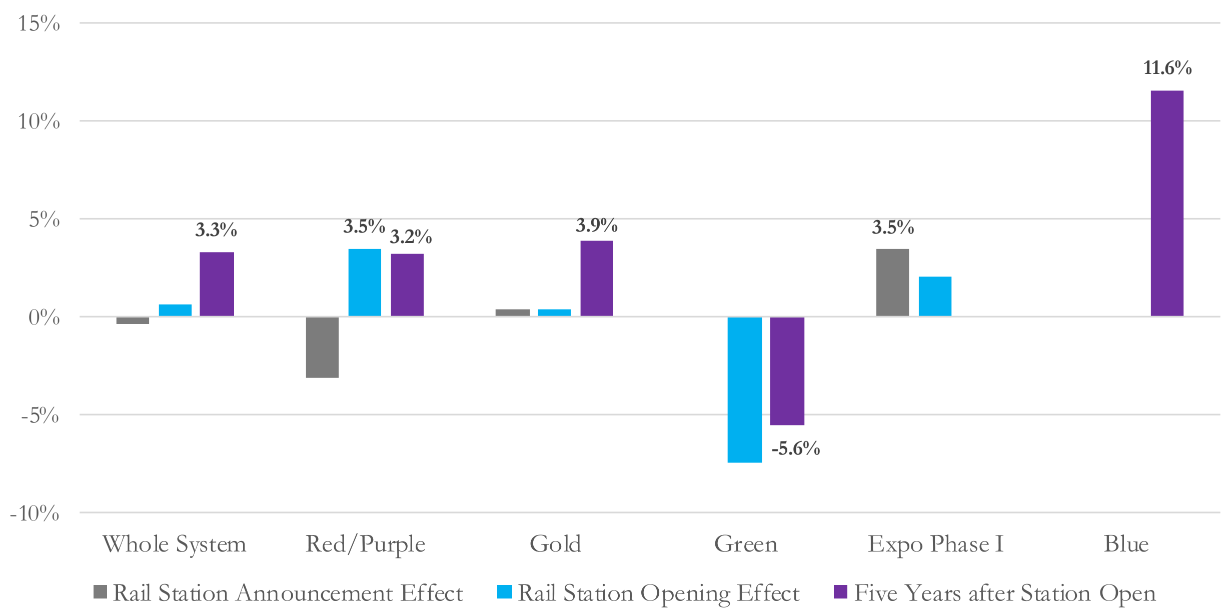
3. The heightened competition for a fixed supply of housing results in the displacement of existing, lower-income households, or increased out-mobility rates for lower-income households.

Key Finding #1: When looking at all incomes together, using a **panel fixed effects (FE) model**, there is evidence of displacement from Red/Purple line station areas coincident with station openings (3.5% increase in out-mobility as a proportion of baseline out-mobility) and five years after openings (3.2%). We also find evidence of displacement from Gold line station areas five years after station openings (3.9%); Blue line station areas five years after station openings (11.6%); and Expo Phase I line station areas upon station announcements (3.5%). We also identify a significant *decrease* in out-mobility rates from Green line station areas five years after opening. See **Executive Summary Figure 1** below for graphical depiction; see Appendix Table D1 for panel FE model output, L.A. Metro Rail system-wide and by timing; see Appendix Table D2 for full panel FE model output by rail corridor and timing. Impact sizes reported in parentheses are calculated by dividing regression model's estimated average treatment-on-treated coefficient by its estimated constant, the latter of which represents baseline mobility.

Executive Summary Figure 1. Panel FE Model's Estimated Rail Station Effects by Timing, Rail System-wide and by Rail Corridor

Weighted by baseline population in neighborhood; Standard errors clustered by station-control area pair; Data values displayed only for statistically significant results



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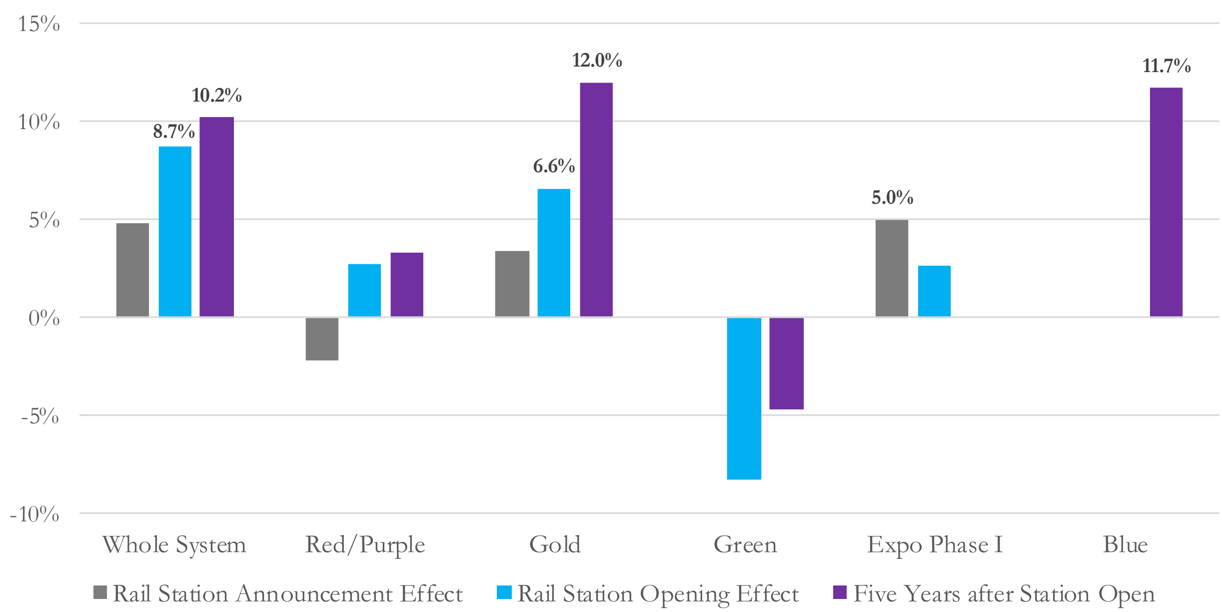
When looking at all incomes together, using a **difference-in-difference (DID) model**, there is evidence of displacement from Gold line station areas coincident with station openings (6.6%) and five years after openings (12.0%). We also find evidence of displacement from Blue line station areas five years after opening (11.7%), as well as Expo Phase I line station areas upon station announcements (5.0%). See **Executive Summary Figure 2** below for graphical depiction; see Appendix Table D1 for DID model output, L.A. Metro Rail system-wide and by timing; see Appendix Table D3 for full DID model output by rail corridor and timing. Impact sizes reported in parentheses are calculated by dividing regression model's estimated average treatment-on-treated coefficient by its estimated constant, the latter of which represents baseline mobility.

Executive Summary Figure 2. DID Model's Estimated Rail Station Effects by Timing, Rail System-wide and by Rail Corridor

Weighted by baseline population in neighborhood; Standard errors clustered by station-control area pair; Data values displayed only for statistically significant results



Key Finding #2: When disaggregating effects by our four income categories, we find the following by rail corridor. Please see **Table 3** in Section 4 of this report for a list of significant results. We report here the instances where our models consistently identified significant effects in the same direction for particular income categories, by rail corridor and timing. These results are more often significant at the 5% level at higher income levels.

1. For the Red/Purple line, our models identify significant and positive effects of stations on their areas' out-mobility rates for Middle and Upper Income households, both coincident with station openings (estimated impact range of 9.9%-13.3%) and five years after station openings (impact range of 9.2%-13.1%).
2. For the Gold line, our models similarly identify significant and positive effects of stations for Middle and Upper Income households, upon rail station announcement (7.5%-8.7%), coincident with station openings (5.9%-11.6%), and five years after station openings (9.7%-15.9%).
3. For the Blue line five years after station openings, our models identify significant and positive effects on station areas' out-mobility rates for all income groups. For Lowest Income households, we estimate an impact range of 8.1%-12.9%; for Low Income households, we estimate an impact range of 8.6%-8.8%; for Lower-Middle Income households, we estimate an impact range of 11.7%-13.5%; and for Middle and Upper Income households, we estimate an impact range of 15.5%-21%.
4. For the Expo Phase I line upon station announcement, we identify a significant and positive impact of 4.5%-5.9% on the out-mobility rate of Lowest Income households.

See Appendix Tables D5, D6, and D7 for full panel FE and DID model output by timing, rail corridor, and income. Impact sizes reported in parentheses are calculated in similar methodology to that mentioned in **Key Finding 1**.

Key Finding #3: Our results reported in **Key Finding 2** indicate heterogeneity in move-out (*i.e.*, displacement) effects associated with rail. The effect of a rail corridor on move-out rates depends on localized context – both neighborhood and likely the state of the real estate market. For the Red/Purple line and Gold line, our highest income category of households is the only with a consistently identified, significant increase in out-mobility rates. For the Blue line five years after opening, we identify significant effects on all income groups' move-out rates. In contrast to both of the above, for the Expo Phase I line, we identify a significant effect upon rail station announcements and for the Lowest Income category. Therefore, our analysis does not support the idea that the largest increases in out-mobility rates always occur at the lowest income level.

Key Finding #4: From a descriptive perspective, the income composition of station areas has shifted notably over time, with the population of Middle and Upper Income households (>80%) growing at a greater rate than lower income categories. This is true for each rail corridor and suggests that station areas have indeed gentrified over time.

Executive Summary Table 1. Household Population Growth Rates of Station Areas by Income Category and Rail Corridor, 1993-2012

Absolute Growth Rate = (Population in 2012 / Population in 1993) – 1

Station Areas	Income Category	Los Angeles County	Red/Purple Line	Gold Line	Blue Line	Green Line	Expo Line
Absolute Growth Rate	<30% AMI	35%	23%	4%	29%	34%	17%
	30-50% AMI	36%	47%	6%	38%	32%	19%
	50-80% AMI	30%	61%	9%	32%	22%	9%
	>80% AMI	52%	92%	31%	58%	47%	14%
	Total	40%	46%	12%	38%	33%	15%

We observe the same trend in Los Angeles County as a whole, indicating that at least some of station areas' gentrification is likely attributable to a County-wide trend. This reinforces the importance of our statistical models' control areas and emphasis on out-mobility rates, both of which help isolate population dynamics attributable to rail stations themselves.

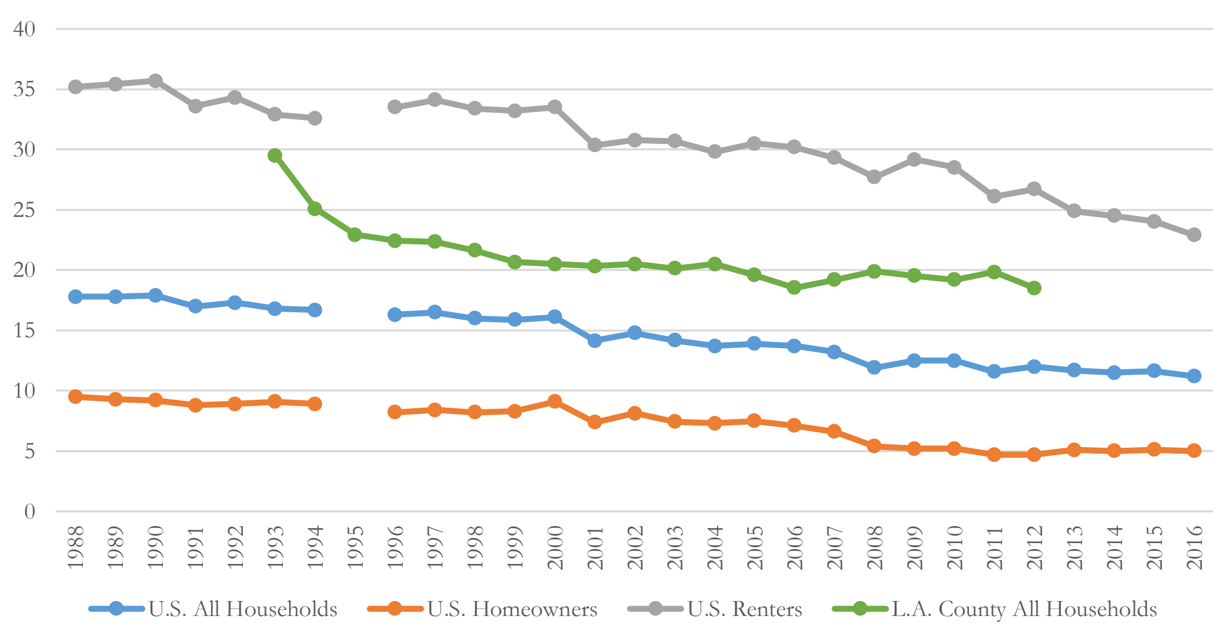
Conclusion: We underscore the need for future research to continue uncovering the link between rail transit, gentrification, and displacement. We believe a critical lens through which future research should view this nexus is housing tenure, *i.e.* homeowners versus renters. While unable to measure it in this study, we theorize exclusionary displacement may also be occurring, whereby lower-income households cannot afford to move into gentrifying station areas. Fertile areas remain for future investigation of rail transit's displacement effects.

Introduction

Household mobility is a central feature of U.S. urban life. Moving from one location to another is not inherently good or bad. For an individual household, the event of moving could improve its lifestyle in terms of housing, neighborhood, or employment; it could also lead to decreased health or educational outcomes (Morris, Manley, & Sabel, 2018). Too frequent, unexpected, or involuntary moves have been found to be detrimental to the health and well-being of members of affected households, both immediately after such moves as well as later in the members' lifetimes (Jelleyman & Spencer, 2018; Morris et al., 2018, Goldsmith, Britton, Reese, & Velez, 2017; Cox, Henwood, Rodnyansky, Wenzel, & Rice, 2017). For sub-populations like low-income, minority, or elderly households, frequent, unexpected, and involuntary moves are even more likely to be detrimental (Jelleyman & Spencer, 2008; Morris et al., 2018; Goldsmith et al., 2017; Cox et al., 2017).

Mobility rates can differ across households for many reasons. As we show below (see **Figure 1**), household tenure may play a large role, with households who rent experiencing higher rates of mobility. Households who rent may be especially exposed to neighborhood change, such as gentrification. Just like households, neighborhoods differ in their mobility levels, due to differences in housing stock and tenure, as well as other sociodemographic characteristics of their residents (*e.g.*, household income). Still, most neighborhoods tend to be stable over time in terms of their sociodemographic composition relative to other neighborhoods (Malone & Redfearn, 2018), suggesting relatively constant rates of mobility – both mobility moving out ("out-mobility") and mobility moving in ("in-mobility") – for their various sociodemographic sub-populations.

Figure 1. Annual Mobility Rate by Housing Tenure for United States, and Aggregate Annual Mobility Rate for Los Angeles County Households



When a neighborhood experiences a change in its desirability and, hence, changes in its housing and rent values, abandonment or gentrification of that neighborhood may occur. In either case, households may move away suddenly in large numbers, resulting in out-mobility rates for particular socio-demographic group that are substantially higher than their corresponding baseline out-mobility rates – we refer to this phenomenon as displacement. Out-mobility rates' far exceeding their baseline levels, *i.e.*, displacement, may result in negative impacts for certain sociodemographic groups. As we mention above, this should be especially true for low-income households, who are limited in where else they can move. This last point is a major motivating factor for our research.

Scholars have characterized displacement (within which our definition falls) as the result of other urban processes, including neighborhood abandonment (Marcuse, 1985) and neighborhood gentrification (Grier & Grier, 1978). Typically, gentrification is defined as the change in neighborhood composition toward a greater share of young, white, higher-income, and higher educational attainment households, often in older and disinvested neighborhoods within an urban area (Marcuse, 1985). Gentrification of a neighborhood creates market competition between existing residents and in-movers for the neighborhood's existing housing supply; existing residents who lose this competition may thereby experience displacement. Scholars and advocates have documented a wide array of causes of gentrification (*e.g.*, Zuk et al., 2015; Zuk, Bierbaum, Chapple, Gorska, & Loukaitou-Sideris, 2017). In doing so, they have also attempted to empirically connect gentrification with displacement with mixed results (Zuk et al., 2015; Zuk et al., 2017).

Within this report, we reexamine the potential link between gentrification and displacement at the neighborhood level. We focus on a well-documented cause of gentrification – public investment in rail transit – and test whether it directly effects displacement. We select rail transit for several reasons. First, rail stations represent a large and long-term change to a neighborhood's built environment. Second, they increase transportation access and lower transportation costs for area residents, which theoretically could redress inequities in access across sociodemographic groups. Third, rail transit is a significant public investment that is allocated to only certain neighborhoods; hence, it is valuable to understand rail stations' effects at the neighborhood level. Fourth, evidence suggests that public transit attracts higher-income, higher-educated, and young households to neighborhoods (Freeman, 2005; Kahn, 2007; Zuk et al., 2017). Fifth, rail transit tends to increase nearby land values and housing prices (*e.g.*, Bartholomew & Ewing, 2011; Higgins & Kanaroglou, 2016); theoretically, increased land values and housing prices should result in increased rent prices too. In sum, public investment in rail transportation may significant alter neighborhoods' built environments *and* sociodemographic characteristics, introducing a potential association between rail transit and displacement, likely via neighborhood gentrification.

Most previous studies of households' displacement from neighborhoods have not considered the presence of rail transit as a salient factor (*e.g.*, Ellen & O'Regan, 2011; Freeman, 2005; Freeman & Braconi, 2004; Newman & Wyly, 2006; Vigdor et al., 2002). Those studies that have considered the presence of rail transit and neighborhood gentrification have either not extended their analyses to displacement (*e.g.*, Dawkings & Moeckel, 2016; Grube-Cavers & Patterson, 2015; Kahn, 2007; Lin, 2002), found mixed results on the relationship between rail transit and neighborhood displacement (Ong, Zuk, Pech, & Chapple, 2017), or do not consider neighborhood-level displacement (Delmelle & Nilsson, 2018). Data and measurement limitations have typically precluded the above studies from adequately assessing the relationship between and impact of rail transit on neighborhood displacement, as embodied by changes in neighborhood out-mobility (Rayle, 2015; Zuk et al., 2015; Zuk et al., 2017).

To address these limitations, our report uses a rich longitudinal database of more than 100 million tax filer records over a 21-year time period estimate the effect of rail transit on neighborhood out-mobility rates, which we use a proxy for displacement. This dataset from the California Franchise Tax Board (FTB) enables us to track annual, neighborhood-level out-mobility rates for Los Angeles County, California between 1993 and 2013. We choose Los Angeles County because of its immense investment in rail transit over the past three decades, with 93 new stations opened since 1989.

We use the FTB data to answer our main research question: Does the introduction of a rail station to a neighborhood significantly change the out-mobility rates of that neighborhood's households and, if so, does this indicate displacement? We hypothesize that the introduction of rail transit to a neighborhood significantly and differentially increases the out-mobility rates (*i.e.*, the displacement) of lower-income households above their baseline levels. By differentially, we mean that although the presence of rail transit may also significantly increase the out-mobility rates of higher-income households, it does so to a lesser extent than for lower-income households.

We examine this research question in a number of ways, including: (a) does the rail station effect occur at the announcement of a rail station being constructed, upon rail station opening, or five years after opening? (b) do effects vary by rail corridor.

The remainder of our report describes our data, measurements, and statistical methodology (Section 3); presents the results of our descriptive and modeling analyses (Section 4); and concludes with a discussion of said results (Section 5). At a broad level, our body of evidence regarding the potential for rail stations to cause significant displacement of households is mixed, which is consistent with the existing literature. Contrary to our hypothesis, our strongest evidence is for out-mobility rates of higher-income households in neighborhoods receiving rail station investments. Given these results, we underscore the need for future research to continue uncovering the link between rail transit, gentrification, and displacement.

2. Data and Methods

2.1 Data

Measuring residential mobility at the neighborhood level is challenging within the U.S. context, due to the lack of sufficient data at fine temporal and spatial scales. Most data sources used in previous studies have encountered: large gaps in time between survey responses (the decennial census), non-representativeness at the neighborhood level (American Community Survey, U.S. Current Population Survey, Panel Study of Income Dynamics, American Housing Survey, New York City Housing and Vacancy Survey, etc), or lack of comparison group within the same metropolitan area (Making Connections Survey).

We overcome these issues by utilizing 21 consecutive years of household-level income tax filing data provided by the California Franchise Tax Board (FTB). This dataset contains all households who ever filed taxes for Los Angeles County from 1993 to 2013 in Los Angeles County, equivalent to over 100 million observations total and approximately 4.8 million per year. For households who moved into or out of Los Angeles County, the FTB additionally provided the tax file data for any other year they filed California tax returns (even if they lived outside of California in that year). The tax file dataset provided by the FTB includes households' annual income level, state taxes paid, and approximate geographic location (described in greater detail below), along with additional characteristics. A key advantage of using longitudinal income tax data is that we avoid measuring single, transient fluctuations of households' earning levels (Österberg, 2000).

From this information, we construct for each station area a longitudinal panel dataset of household mobility patterns, which we in turn use as a measure of neighborhood-level displacement attributable to the presence of light rail transit. In addition to household data, we geocode rail station locations for all 80 subway and light rail stations opened by L.A. Metro in or before 2013. We do so using geographic information system shapefiles provided by the Southern California Association of Governments (SCAG) (SCAG, 2015). We define a station area as the area composed of all points that are within a half-mile of a particular light rail station (equivalent to a circle with a half-mile radius that is centered on a light rail station). A half-mile represents a walking distance of 15-20 minutes and an approximate catchment area for neighborhood-generated light rail ridership; it is therefore frequently used in considerations of transit-oriented development policies (Guerra, Cervero, & Tischler, 2011). Defining a station area at any smaller scale (*e.g.*, a quarter-mile area) did not yield sufficient counts of "treated" households, *i.e.*, households situated inside a station area, for our analytical purposes.

2.2 Control Areas

We aim to assess the relationship between neighborhood-level out-mobility and the presence of rail transit, before and after rail stations open. However, what if a new rail transit corridor or station affects other, more distant parts of the city in the same way? Or, what if out-mobility rates for neighborhoods fluctuate generally, in ways unrelated to the absence or presence of rail transit? To better isolate the relationship of rail transit on rail-proximate neighborhoods, we test the relationship against a counterfactual. For each station area (as defined above in Section 2.1), we select a paired control neighborhood. We define a station area's control neighborhood as a circle with half-mile radius that is centered on a major road intersection and that is situated 0.5 to 3 miles away from the station area's rail station location. The control neighborhood also has similar sociodemographic characteristics to its paired station area, across income, racial and ethnic identification, housing tenure, and educational status. See Appendix A for the control area locations for each of the 80 rail stations in our sample.

2.3 Geocoding Households and Calculating Mobility Rates for Station and Control Areas

To assess the relationship between neighborhood out-mobility and the introduction of rail transit, we determine whether: (1) each household in our dataset is located within either a station area or a control area in year *t* (as we define in Sections 2.1 and 2.2, respectively); and (2) whether that household moves out of that station area or control area between years *t* and *t + 1* of our dataset.[2]

To make the first part of this determination, we approximate the geographic location of each household in our tax filing dataset relative to the geographic locations of the nearest light rail transit station and control area. We approximate each household's geographic location in a given year by geocoding the 5-digit or 9-digit zip code listed on its tax file in that same year (the FTB suppressed filers' addresses due to confidentiality reasons).[i] Our main results presented in Section 4, along with our descriptive statistics presented in Section 3, focus on households who are located within either a station area or a control area in year *t*.

To make the second part of our determination – whether a household moves out of a station area or control area – we identify households that physically moved out between years *t* and *t + 1* by at least 0.5 miles. Smaller moves are especially likely to represent noise from geocoding over time or changes in 9-digit zip code coordinates, which are periodically adjusted by the U.S. Postal Service.

About 15% of households in our geocoded dataset appear in year *t* but not year *t + 1*, due to incomes dropping below the filing income threshold, moving out of California and not filing any California taxes, and death. Especially in cases of incomes falling near the filing threshold, households may reappear in the dataset in years after *t + 1*. In our calculation of a station area or control area's out-mobility rate, both the numerator and denominator include only households present in the station area or control area in both years *t* and *t + 1*. We calculate the mobility rate as follows:

[2] Where years *t* and *t + 1* are any consecutive years in our longitudinal tax filing dataset, which spans 1993-2013, equivalent to an observation period of 21 years.

$$Mobility\ rate_t = \frac{(Number\ of\ filers\ changing\ location\ by\ at\ least\ 0.5\ miles\ from\ year\ t\ to\ t+1) \mid (observed\ in\ t\ and\ t+1)}{Total\ number\ of\ filers\ in\ year\ t\ that\ are\ observed\ in\ years\ t\ and\ t+1}$$

For corroborative purposes, we calculate a County-wide (*i.e.*, for all households with zip-code data in our tax filing longitudinal dataset), average annual mobility rate over all years of 21% (Rodnyansky et al., 2018). This compares favorably with other mobility studies of Los Angeles County. For example, Clark and Ledwith (2006) derived an 18% annual mobility rate for Los Angeles County households using a sample of 2,644 households in 65 neighborhoods observed from 2002-2006. Coulton, Theodos, and Turner (2012) also found a 19% annual mobility rate in their survey of 10 low-income and changing neighborhoods in metropolitan areas across the United States. See **Figure 1** in Section 1 for a comparison of our calculated annual County-wide rates to the national rates for all households, homeowners, and renters.

Using this same methodology, we calculate out-mobility rates for each of our 80 station areas and their paired control areas, which are displayed in Appendix B. To understand how rail station effects on neighborhood out-mobility may vary by income, we also compute out-mobility rates for four income groups within each station area and control area, which are defined relative to the area median income (AMI) for the Los Angeles – Long Beach Metropolitan Statistical Area (see Appendix C for AMI values by year). These income groups are defined as: Lowest Income (less than 30% of AMI, or less than $15,000 in 2013); Low Income (30-50% of AMI, or $15,000 - $25,000 in 2013); Lower-Middle Income (50-80% of AMI, or $25,000-$40,000 in 2013); and Middle and Upper Income (above 80% of AMI, or more than $40,000 in 2013). We use FTB data on annual household income to categorize each household into one of these income categories; we do so for each year a household is observed in our dataset.

The station and control areas whose out-mobility rates we study have differing population levels (see Appendix B). In our main quantitative analysis presented in Section 4, we estimate the rail station effect for an "average" rail station in the L.A. Metro system or in a particular rail corridor. Particularly large or small stations may unduly influence the estimates and/or may not represent an "average" rail station. The sample restrictions and geocoding methodology we have discussed in this Section introduce additional differences in the station and control areas' sample sizes. In all of our statistical models, we therefore weight observations by the household baseline population (after applying all of the sample restrictions noted in this Section).[ii]

2.4 Statistical Models

To estimate the effects of the presence of new rail transit on proximate neighborhoods' out-mobility rates, and therefore potential displacement, we use statistical models to compare between our treatment and control areas while controlling for spatial and temporal variations. We measure the effects of rail opening on station and control areas' out-mobility rates; for comparative purposes, we also consider the effects of rail announcement and five years after completion. Having estimated the effects of rail transit stations on station areas' out-mobility rates, we compare them to average out-mobility rates in each neighborhood, which acts as a proxy for the displacement impact of rail transit stations.

We use two different statistical models, a panel fixed effects (FE) model and a difference-in-difference (DID) model, to estimate the effect of rail transit stations on station areas' out-mobility rates. The panel FE model takes advantage of longitudinal data and controls for the presence of unobserved, time-invariant variables with time-invariant effects (Allison, 2009). In our panel FE model, we use a dummy variable for each year as well as each station and control area to indicate whether a rail station is present. Since the errors in this panel FE model are potentially serially correlated and/or heteroskedastic, we use cluster-robust standard errors at the station-control area pair level (Cameron & Trivedi, 2005). The DID model is an Ordinary Least Squares (OLS) regression model that produces a causal estimate of rail stations' average effect on station areas by comparing station areas' out-mobility rates to control areas' before and after the introduction of rail to station areas (Cameron & Trivedi, 2005). In both our panel FE and DID models, the dependent variable used is the out-mobility rate of a particular station or control area in a particular year. Our model equations are as follows:

Equation 1: Panel Fixed Effects (FE) Model without Incomes

$$Y_{it} = \alpha + \delta * Treatment * Post_{it} + \sum_{t=1}^{t} \varphi_j * Year_t + \sum_{i=1}^{i} \gamma_j * Neighborhood_i + \epsilon_{it}$$

Y represents the mobility rate for station/control area *i* in year *t*. *Treatment* is a binary variable that equals "1" for station areas and "0" for control areas. *Post* is a binary variable that equals "1" if the treatment has already occurred (*i.e.*, a rail station has opened), and "0" otherwise. *Treatment*Post* is the interaction between *Treatment* and *Post* and is our variable of interest. The constant term α represents the baseline mobility rate. ϕ and γ represent year and neighborhood (*i.e.*, station/control area) fixed effects, respectively.

Equation 2: Difference – in – Difference (DID) Model without Incomes

$$Y_{it} = \alpha + \beta * Treatment_i + \gamma * Post_t + \delta * Treatment * Post_{it} + \epsilon_p$$

Y represents the mobility rate for station/control area *i* in year *t*. *Treatment* is a binary variable that equals "1" for station areas and "0" for control areas. *Post* is a binary variable that equals "1" if the treatment has already occurred (*i.e.*, a rail station has opened), and "0" otherwise. *Treatment*Post* is the interaction between *Treatment* and *Post* and is our variable of interest. The constant term α represents the baseline mobility rate.

We additionally consider our four income categories in these models as follows:

Equation 3: Panel FE Model with Incomes

$$Y_{it} = \alpha + \omega * Income_w + \delta * Income_w * Treatment_i * Post_t + \sum_{t=1}^{t} \varphi_j * Year_t + \sum_{i=1}^{i} \gamma_j * Neighborhood_i + \epsilon_{it}$$

Equation 4: DID Model with Incomes

$$Y_{it} = \alpha + \omega * Income_w + \beta * Income_w * Treatment_i + \gamma * Income_w * Post_t + \delta * Income_w * Treatment_i * Post_t + \in_p$$

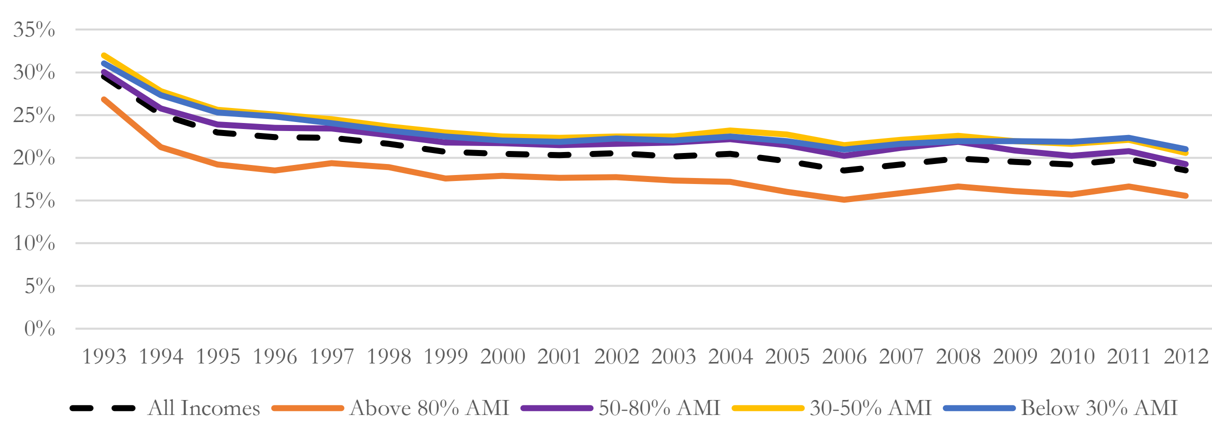
3. Descriptive Statistics

Before addressing the effects of rail station development on neighborhood out-mobility rates to estimate potential displacement, we document the baseline mobility rates for Los Angeles County and each station area, by rail corridor. We also document the changing size and income composition of rail station corridors versus our control areas and summarize growth by income. These descriptive analyses will ground our statistical models in the evolution of the neighborhoods in the study area from 1993-2013.

3.1 Baseline Mobility Rates

As we mentioned in Section 2.3, of the Los Angeles County households in our longitudinal tax filing dataset that possess zip codes in years *t* and *t + 1*, an average of 21% move at least 0.5 miles on an annual basis. This 21% does not vary substantially by income: 23% of households with incomes below 80% of AMI (all households but Middle and Upper Income households) move in a given year, while 18% of Middle and Upper Income Households move in a given year (Rodnyansky et al., 2018). Assessing annual out-mobility rates across the 21 years of our dataset reveals decreasing out-mobility by income over time. Any hypothesis predicting displacement would run against this trend.

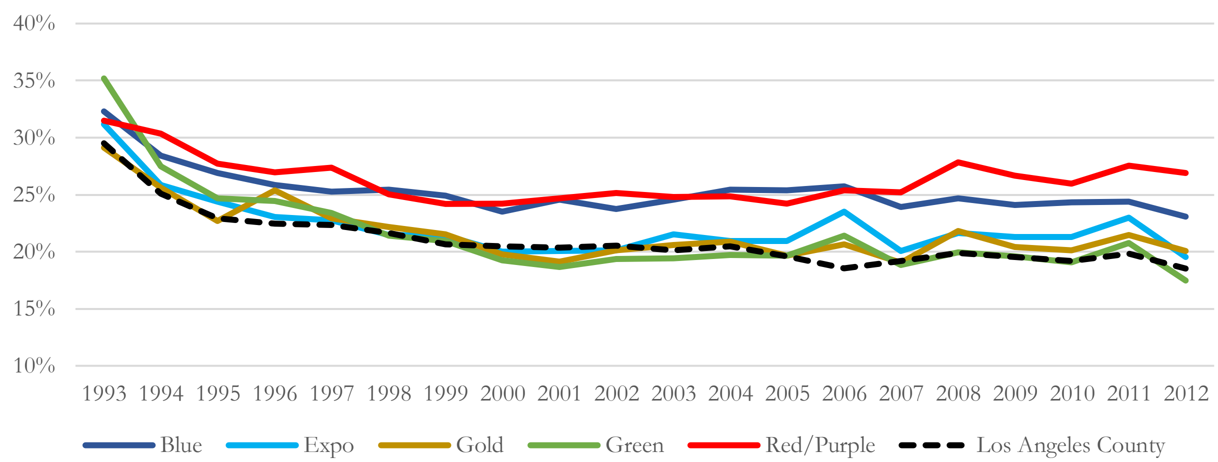
Figure 2. Annual Average Out-Mobility Rates by Income Category for Los Angeles County



In aggregate, our 80 rail station areas are located in dense neighborhoods relative to the County's average residential density; these areas also have higher shares of low-income, renter, foreign-born, and non-White and/or Hispanic households (Boarnet et al., 2015). We thus expect higher baseline out-mobility rates along L.A. Metro rail corridors compared to the overall County's, even without considering the effects of rail stations themselves. **Figure 3** depicts average out-mobility rates by L.A. Metro rail corridor versus the County, calculated by year. The

Red/Purple and Blue lines have baseline out-mobility rates that typically exceed the County average by at least 5 percentage points; however, the Expo Phase I, Gold, and Green lines have baseline rates very similar to the County average across our period of observation. These differences across corridors reflect the diversity and size of the L.A. Metro rail system as well as the County in general.

Figure 3. Annual Average Out-Mobility Rates by L.A. Metro Rail Corridor/Line

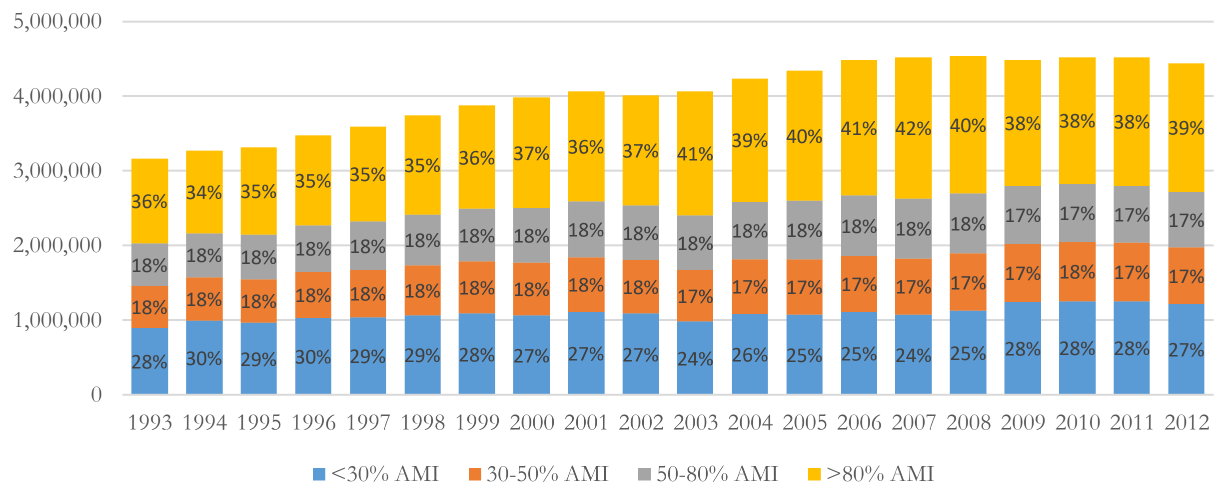


3.2 Changes in Station and Control Areas' Neighborhood Compositions over Time

3.2.1. Los Angeles County-wide statistics

On a per-year basis, our restricted longitudinal tax filing dataset (restricted to remove households with missing geographic data in at least one year in a consecutive year pairing) averages 4 million households observed County-wide. The number of households observed in the County by year has increased by 40% over our dataset's observation period, from 3.2 million in 1993 to 4.5 million in 2013. As of 2012, 27% of households in our dataset were considered Lowest Income (incomes below 30% of AMI); 35% were considered Low or Lower-Middle Income (30% - 80% of AMI); and 38% were considered Middle and Upper Income (greater than 80% of AMI). From 1993 to 2012, the number of households considered Middle and Upper Income has increased by over 50%, a rate that slightly exceeds the other income categories'. This fact is reflected in the growing share of households in our dataset considered Middle and Upper Income (see **Figure 4**).

Figure 4. Household Population of Los Angeles County by Income Category



3.2.2. Station and control area statistics

At the L.A. Metro rail corridor level, the Blue and Red/Purple lines' neighborhoods (*i.e.*, station areas) have the highest population levels in our restricted dataset, averaging approximately 90,000 and 80,000 households observed per year of our dataset, respectively. The Gold Line is next in size, with approximately 65,000 households observed per year in its station areas. The Expo Phase I and Green Lines are the smallest in population levels, with approximately 27,000 and 21,000 observed per-year on average, respectively. Within our restricted dataset, 35% of households in the station areas of the Blue, Gold, Green, or Expo Phase I rail corridors are considered Lowest Income between 1993 and 2012; in contrast, 41% of households in Red/Purple line station areas fall within the same category.

The following **Table 1** shows the change in income compositions of rail corridors' station and control areas, from 1993 to 2012. We note that for a given rail corridor, the change in its station areas' income composition does not mirror that in its control areas' composition. For each rail corridor other than the Expo Phase I line, station areas' share of Middle and Upper Income households (>80% AMI) has increased by at least as much as control areas'.

Table 1. Household Population by Income Category for Rail Corridors' Station and Control Areas, 1993-2012

	Income Category	Station Areas 1993	Station Areas 2012	Percentage Change	Control Areas 1993	Control Areas 2012	Percentage Change
Red/Purple Line	<30% AMI	45%	38%	**-7%**	37%	35%	**-2%**
	30-50% AMI	22%	23%	**1%**	21%	21%	**0%**
	50-80% AMI	16%	18%	**2%**	17%	18%	**1%**
	>80% AMI	16%	21%	**5%**	25%	26%	**1%**
Gold Line	<30% AMI	36%	34%	**-2%**	35%	34%	**-1%**
	30-50% AMI	22%	21%	**-1%**	23%	22%	**-1%**
	50-80% AMI	18%	18%	**0%**	20%	18%	**-2%**
	>80% AMI	23%	27%	**4%**	22%	26%	**4%**
Blue Line	<30% AMI	37%	34%	**-3%**	35%	37%	**2%**
	30-50% AMI	23%	23%	**0%**	23%	25%	**2%**
	50-80% AMI	19%	18%	**-1%**	19%	18%	**-1%**
	>80% AMI	22%	25%	**3%**	23%	21%	**-2%**
Green Line	<30% AMI	35%	36%	**1%**	26%	31%	**5%**
	30-50% AMI	26%	25%	**-1%**	20%	22%	**2%**
	50-80% AMI	21%	19%	**-2%**	22%	21%	**-1%**
	>80% AMI	18%	19%	**1%**	32%	26%	**-6%**
Expo Phase I Line	<30% AMI	35%	36%	**1%**	37%	38%	**1%**
	30-50% AMI	23%	23%	**0%**	25%	24%	**-1%**
	50-80% AMI	20%	19%	**-1%**	21%	18%	**-3%**
	>80% AMI	22%	22%	**0%**	17%	20%	**3%**

Tables 2.1 and **2.2** show the growth rates in population levels by rail corridor and income category from 1993 to 2012, comparing station areas (**Table 2.1)** to control areas (**Table 2.2**). Per the "Total" rates shown in **Table 2.1**, each L.A. Metro rail corridor's station area population has increased between 1993 and 2012; these increases, though, have occurred disparately across corridor. The Red/Purple line station areas have experienced the greatest percentage

increase, at 46%. Both the Blue and Green lines' station area populations have increased by over 30% over the same period—38% and 33%, respectively. The Gold and Expo lines' station areas have grown by only 12% and 15% respectively. Furthermore, for control area populations, all L.A. Metro rail corridors but the Green line also experienced increases between 1993 and 2012 (see the "Total rates" shown in **Table 2.2** below). As with the corridors' station area populations, these increases have occurred disparately across corridors. However, changes in a corridor's control area population over time do not parallel changes in its station area population.

Tables 2.1 and **2.2** also disaggregate the absolute growth rates and compound annual growth rates for rail corridors' station and control area population levels by income category. Every income category of each rail corridors' station area population has increased, although the rate of growth differs by both rail corridor and income category (see **Table 2.1**). Still, the number of Middle and Upper Income households (incomes greater than 80% of AMI) has substantially grown in station areas across all five rail corridors studied, *e.g.*, the Red/Purple line. Turning to rail corridors' control areas, the Red/Purple line, Gold line, and Expo Phase I lines' Middle and Upper Income populations in these areas also exhibit the highest growth rates (see **Table 2.2**).

Tables 2.1-2.2. Household Population Growth Rates for Station and Control Areas, by Income Category and Rail Corridor

Absolute Growth Rate = (Population in 2012 / Population in 1993) – 1

Compound Annual Growth Rate (CAGR) = (Population in 2012 / Population in 1993)^(1/(2012-1993)) – 1

Station Areas	Income Category	Los Angeles County	Red/Purple Line	Gold Line	Blue Line	Green Line	Expo Line
Absolute Growth Rate	<30% AMI	35%	23%	4%	29%	34%	17%
	30-50% AMI	36%	47%	6%	38%	32%	19%
	50-80% AMI	30%	61%	9%	32%	22%	9%
	>80% AMI	52%	92%	31%	58%	47%	14%
	Total	40%	46%	12%	38%	33%	15%
Compound Annual Growth Rate (CAGR)	<30% AMI	1.6%	1.1%	0.2%	1.3%	1.6%	0.8%
	30-50% AMI	1.6%	2.1%	0.3%	1.7%	1.5%	0.9%
	50-80% AMI	1.4%	2.6%	0.4%	1.5%	1.1%	0.5%
	>80% AMI	2.2%	3.5%	1.4%	2.5%	2.0%	0.7%
	Total	1.8%	2.0%	0.6%	1.7%	1.5%	0.7%

Control Areas	Income Category	Los Angeles County	Red/Purple Line	Gold Line	Blue Line	Green Line	Expo Line
Absolute Growth Rate	<30% AMI	35%	20%	2%	33%	11%	31%
	30-50% AMI	36%	25%	-1%	39%	3%	23%
	50-80% AMI	30%	28%	-2%	21%	-12%	7%
	>80% AMI	52%	35%	31%	13%	-25%	52%
	Total	40%	26%	7%	28%	-7%	28%
Compound Annual Growth Rate (CAGR)	<30% AMI	1.6%	0.9%	0.1%	1.5%	0.5%	1.4%
	30-50% AMI	1.6%	1.2%	0.0%	1.8%	0.2%	1.1%
	50-80% AMI	1.4%	1.3%	-0.1%	1.0%	-0.7%	0.4%
	>80% AMI	2.2%	1.6%	1.4%	0.6%	-1.5%	2.2%
	Total	1.8%	1.2%	0.4%	1.3%	-0.4%	1.3%

For each rail corridor other than the Expo Phase I line, **Tables 2.1** and **2.2** indicate larger growth in Middle and Upper Income households (>80% AMI) in station areas relative to control areas. For example, the Red/Purple line's absolute growth in Middle and Upper Income households (>80% AMI) in station areas in 92%; in control areas, the absolute growth for similar households is only 35%. The same holds true for the Blue, Green, and Gold lines. Although not definitive, this suggests that these rail-proximate neighborhoods have gentrified over our period of study (1993 – 2013) to a greater degree than their control areas. Such gentrification appears to be a very localized process in these areas, given that our control pairs are on average only 1.5 miles away from their accompanying rail stations. Finally, we note that growth in our Expo Phase line control areas' Middle and Upper Income population far outpaces that in its station areas.

It is possible that these compositional changes in station areas' populations are associated with similar increases in their housing stock. This is unlikely, however, given the housing permitting and construction patterns in Los Angeles County during this time (Taylor, 2015; U.S. HUD, n.d.). In fact, these trends in compositional change correlate well with the Urban Displacement Project's findings that at least 15% of census tracts in Los Angeles County at risk of gentrification had, in fact, gentrified between 1990 and 2013. They also highlight the potential for a link between the introduction of rail transit stations, gentrification, and displacement within Los Angeles County.

4. Results of Statistical Modeling

4.1 Rail Stations' Estimated Effects, System-wide and by Rail Corridor, All Households

The results we report in this Section and Section 4.2 stem from our use of the two models – panel FE and DID – that we described in Section 2.4. At a L.A. Metro rail system-wide level, our **panel FE model** identifies a significant effect on out-mobility rates only at five years after station openings; this effect is equivalent to a 1% marginal increase in the system-wide out-mobility rate (see Appendix Table D1). In contrast, utilizing our **DID model** on a system-wide level, we find a significant and positive effect of rail stations both coincident with station openings and five years after openings – 1.9% and 2.2% marginal increases, respectively (see Appendix Table D1). Rail station announcement does not have a statistically significant effect on station areas' out-mobility rates on a system-wide basis for either model.

In the remainder of this section, we translate rail stations' estimated marginal effect on station areas' out-mobility rates into "impact sizes". We do so by dividing an estimated marginal effect on out-mobility rate (*i.e.*, our regression model's estimated coefficient of interest) by an estimated baseline out-mobility rate (*i.e.*, the same regression model's estimated constant). See the "Whole System" results reported in **Figures 5** and **6** for a translation of the above marginal effects into impact sizes. **Figures 5** and **6** additionally report our findings regarding station effects at the individual rail corridor level and across all household incomes. See Appendix Tables D2 and D3 for full regression outputs for our **panel FE** and **DID models** at the individual rail corridor level across all household incomes.

Figure 5. Panel FE Model's Estimated Rail Station Effects by Timing, Rail System-wide and by Rail Corridor

Weighted by baseline population in neighborhood; Standard errors clustered by station-control area pair; Data values displayed only for statistically significant results

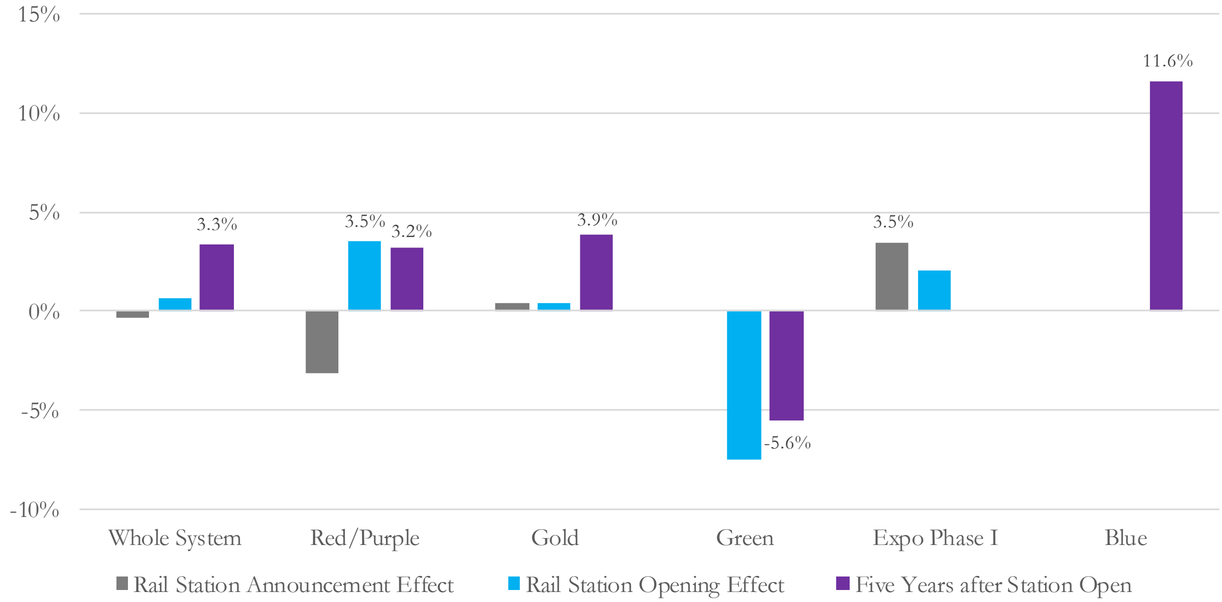
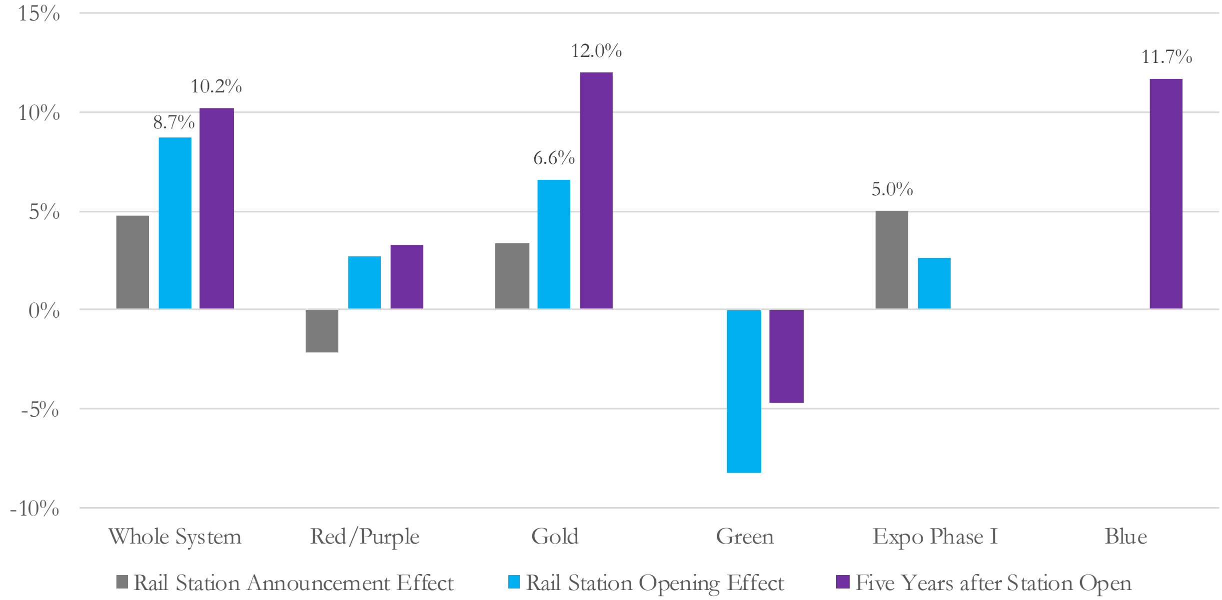


Figure 6. DID Model's Estimated Rail Station Effects by Timing, Rail System-wide and by Rail Corridor

Weighted by baseline population in neighborhood; Standard errors clustered by station-control area pair; Data values displayed only for statistically significant results



When looking at all incomes together, using our **panel FE model** (see **Figure 5**), there is evidence of displacement from Red/Purple line station areas coincident with station openings (3.5% increase in out-mobility as a proportion of baseline out-mobility) and five years after openings (3.2%). We also find evidence of displacement from Gold line station areas five years after station openings (3.9%); Blue line station areas five years after station openings (11.6%); and Expo Phase I line station areas upon station announcements (3.5%). We also identify a significant *decrease* in out-mobility rates from Green line station areas five years after opening. See Appendix Table D1 for panel FE model output, L.A. Metro Rail system-wide and by timing; see Appendix Table D2 for full panel FE model output by rail corridor and timing. Impact sizes reported in parentheses are calculated by dividing regression model's estimated average treatment-on-treated coefficient by its estimated constant, the latter of which represents baseline mobility.

When looking at all incomes together, using our **DID model** (see **Figure 6**), there is evidence of displacement from Gold line station areas coincident with station openings (6.6%) and five years after openings (12.0%). We also find evidence of displacement from Blue line station areas five years after opening (11.7%), as well as Expo Phase I line station areas upon station announcements (5.0%). See Appendix Table D1 for DID model output, L.A. Metro Rail system-wide and by timing; see Appendix Table D3 for full DID model output by rail corridor and timing. Impact sizes reported in parentheses are calculated by dividing regression model's estimated average treatment-on-treated coefficient by its estimated constant, the latter of which represents baseline mobility.

Based on these results, it is clear that stations' impacts on their areas' out-mobility rates differ across transit corridors by timing; we also note some differences depending upon statistical model (see **Figures 5 & 6**). For example, in our rail corridor-level panel FE regressions, only the Red/Purple line stations lead to significant displacement coincident with station openings. In our rail corridor-level DID regressions, only the Gold line stations lead to significant displacement coincident with station openings. We note instances of consistent identification of effects across models as well. Both our models identify a significant and positive impact on Gold line and Blue line station areas' out-mobility rates five years after station openings. We posit that differences between results of our panel FE and DID models indicate factors attributable to year-specific idiosyncrasies, which our panel FE model controls for better than our DID model.

4.2 Rail Stations' Estimated Effects, System-wide and by Rail Corridor, by Household Income

In this Section, we disaggregate our regression model findings from Section 4.1 by household income categories. We find that the impact of rail stations' announcements, openings, and continued operation is not uniform across the income spectrum. In **Table 3**, we present the impact of each significant station effect on out-mobility rate, by rail corridor and by income category. As with our calculated impacts presented in Section 4.1, for each combination of rail corridor and income category, our estimated impact is equivalent to: (a) our estimated effect on households in relevant station areas divided by (b) the baseline out-mobility rates for the same station areas.[3]

In **Table 3** below, we show these impacts as a range to account for both our panel FE and DID model results. We hold that significant results reflect a rate of neighborhood displacement. The "All Incomes" results reported in **Table 3** are the same as those reported in **Figures 5** and **6**; we include them in **Table 3** for reference only.

When disaggregating effects by our four income categories and using a **panel FE model**, there is evidence of displacement by Red/Purple line stations for: Lower-Middle Income (4.5%) and Middle and Upper Income households (13.3%) coincident with station openings, as well as Lower-Middle Income (5.1%) and Middle and Upper Income households (13.1%) five years after station openings. For Gold line stations, there is evidence of displacement for: Middle and Upper Income households upon station announcements (7.5%); Middle and Upper Income households coincident with station openings (5.9%); and Middle and Upper Income households five years after station openings (9.7%). For Blue line stations, there is evidence of displacement for: Lowest Income (8.1%), Low Income (8.6%), Lower-Middle Income (13.5%), and Middle and Upper Income households (21.0%) five years after station openings. For Expo Phase I line stations, there is evidence of displacement for: Lowest Income (4.5%) and Lower-Middle Income households (2.8%) upon station announcements, as well as Lowest Income households coincident with station openings (4.2%). See Appendix Tables D5, D6, and D7 for full panel FE model output by timing, rail corridor, and income. Impact sizes reported in parentheses are calculated by dividing estimated marginal change in out-mobility rate by estimated regression constant, *i.e.*, baseline out-mobility rate.

When disaggregating effects by our four income categories and using a **DID model**, there is evidence of displacement by Red/Purple line stations for: Middle and Upper Income households coincident with station openings (9.9%) and Middle and Upper Income households five years after station openings (9.2%). For Gold line stations, there is evidence of displacement for: Middle and Upper Income households upon station announcements (8.7%); Lower-Middle Income households (5.7%) and Middle and Upper Income households (11.6%) coincident with station openings; and Low Income (10.4%), Lower-Middle Income (11.2%), and Middle and Upper Income households (15.9%) five years after station openings. For Blue line stations, there is evidence of displacement for: Lowest Income (12.9%), Low Income (8.8%), Lower-Middle Income (11.7%), and Middle and Upper Income households (15.5%) five years after station openings. For the Expo Phase I line stations, there is evidence of displacement for Lowest Income households upon station announcements (5.9%). See Appendix Tables D5, D6, and D7 for full DID model output by timing, rail corridor, and income. Impact sizes reported in

[3] These base out-mobility rates are the constants in our regression analyses for specific rail corridor-household income category combinations.

parentheses are calculated by dividing estimated marginal change in out-mobility rate by estimated regression constant, *i.e.*, baseline out-mobility rate.

Table 3. Rail Effect Magnitude Impact on Station Areas' Annual Out-Mobility Rates, by Rail Corridor and by Household Income Category

Impacts shown only when effect is statistically significant. Impact range reflects differences between Difference-in-Difference and panel Fixed Effects models. Regression models weighted by Baseline Population in Station Area/Control Area. Standard errors clustered by Station-Control Area Pair.
** p<0.10 ** p<0.05 *** p<0.01*
Restrictions: FTB data is unavailable to measure Green and Blue lines' announcement effects, Blue line's opening effects, or Expo Phase I line's effects 5 years after station openings.

Rail Station Announcement

	Whole System (N=11,920)		Red/Purple (N=2,400)		Gold (N=3,120)		Green	Expo Phase 1 (N=1,440)		Blue
FE	FE	DID	FE	DID	FE	DID		FE	DID	
All Incomes								3.5%*	5.0%	
Lowest (<30% AMI)	-2.5%*				-3.8%*			4.5%*	5.9%	
Low (30-50% AMI)	-2.3%*									
Lower-Middle (50-80% AMI)								2.8%*		
Middle and Upper (>80% AMI)	5.6%***				7.5%**	8.7%				

Rail Station Opening

	Whole System (N=11,920)		Red/Purple (N=2,400)		Gold (N=3,120)		Green (N=1,840)		Expo Phase 1 (N=1,440)		Blue
	FE	DID	FE	DID	FE	DID	FE	DID	FE	DID	
All Incomes		8.7%**	3.5%*								
Lowest (<30% AMI)					-3.1%*				4.2%*		

Low (30-50% AMI)											
Lower-Middle (50-80% AMI)		11%**	4.5%*			5.7%*					
Middle and Upper (>80% AMI)	6.7%***	16.9%***	13.3%**	9.9%*	5.9%*	11.6%*					

Five Years After Opening											
	Whole System (N=11,920)		**Red/Purple (N=2,400)**		**Gold (N=3,120)**		**Green (N=1,840)**		**Expo Phase 1**	**Blue (N=3,120)**	
	FE	DID	FE	DID	FE	DID	FE	DID		FE	DID
All Incomes	3.3%**	10.2%**	3.2%***		3.9%*	12%**	-5.6%*			11.6%**	11.7%**
Lowest (<30% AMI)		6.5%*								8.1%*	12.9%**
Low (30-50% AMI)		8.8%*				10.4%**				8.6%*	8.8%*
Lower-Middle (50-80% AMI)	4.7%**	12.3%**	5.1%***			11.2%**	-6.3%*			13.5%**	11.7%**
Middle and Upper (>80% AMI)	10%**	16.5%**	13.1%***	9.2%***	9.7%**	15.9%**				21%***	15.5%***

In addition, we also note that we identify significant *reductions* in station areas' out-mobility rates at individual rail corridor and income category levels. The significant negative impacts we identify are never present at the highest income level. Rather, one of these significant negative impacts is identified upon rail station announcement for Lowest Income households along the Gold line (-3.8%); another coincident with station openings for Lowest Income households along the Gold line (-3.1%); and a third five years after station openings for Lower-Middle Income households along the Green line. The latter is the only significant income-specific impact we identify for Green line station areas, regardless of timing.

We consider these findings in Section 5 (our Discussion and Conclusion Section) below.

5. Discussion and Conclusion

In this study, we explore the link between the introduction of rail transit stations and changes in out-mobility rates for households living in the new station areas. We do so as we believe large increases in out-mobility rates can be used as proxies for systematic displacement. As we hypothesize that public investment in rail transit results in the neighborhood-level displacement of lower-income residents from station areas, we conduct our exploration of the link between rail stations and station areas' out-mobility rates across discrete household income categories. In addition to considering the entire L.A. Metro rail system, we narrow our investigation to individual rail corridors, as the neighborhood contexts of station areas tend to differ by rail corridor (see Appendix Table B1). In this respect, our panel FE models are especially helpful, as they remove the influence of any corridor-specific, time-invariant characteristics with time-invariant effects that may impact the relationship between the introduction of a corridor's rail stations and the station areas' out-mobility rates (Allison, 2009).

We find evidence of rail corridor-, income-, and timing-specific displacement effects of stations (see **Table 3**). For the Red/Purple line, our models identify significant and positive effects of stations on their areas' out-mobility rates for Middle and Upper Income households, both coincident with station openings (estimated impact range of 9.9%-13.3%) and five years after station openings (impact range of 9.2%-13.1%). For the Gold line, our models similarly identify significant and positive effects of stations for Middle and Upper Income households, upon rail station announcement (7.5%-8.7%), coincident with station openings (5.9%-11.6%), and five years after station openings (9.7%-15.9%). For the Blue line five years after station openings, our models identify significant and positive effects on station areas' out-mobility rates for all income groups. For Lowest Income households, we estimate an impact range of 8.1%-12.9%; for Low Income households, we estimate an impact range of 8.6%-8.8%; for Lower-Middle Income households, we estimate an impact range of 11.7%-13.5%; and for Middle and Upper Income households, we estimate an impact range of 15.5%-21%. For the Expo Phase I line upon station announcement, we identify a significant and positive impact of 4.5%-5.9% on the out-mobility rate of Lowest Income households.

Given these results, it appears the effect of a rail corridor on move-out rates greatly depends on localized context – both neighborhood and likely the state of the real estate market. For the Red/Purple line and Gold line, our highest income category of households is the only category with a consistently identified, significant increase in out-mobility rates. For the Blue line five years after opening, we identify significant effects on all income groups' move-out rates. In contrast to both of the above, for the Expo Phase I line, we identify a significant effect upon rail station announcements and for the Lowest Income category; but due to data limitations, we are unable to observe the effects 5 years after these stations' openings. Therefore, our analysis does not support the idea that the largest increases in out-mobility rates always occur at the lowest income level. This is especially true given the fact that we identify a couple significant *reductions* in out-mobility rates for Lowest Income households along the Gold line (see **Table 3**).

From our descriptive analyses of the FTB dataset in Section 3, we observe a growing population of households in Los Angeles County and along each of the five rail corridors studied; populations at the County-wide level and in the Red/Purple line's, Blue line's, and Green line's station areas increased by approximately 40-50% between 1993 and 2013. The income compositions of each rail corridor's station areas have dramatically shifted (in terms of share of households) in favor of Middle and Upper Income households, with the exception of the Expo Phase I line's station areas. As we articulate in this report, this relative growth of Middle and Upper Income population in station areas does not appear in our control areas, which suggests a process of gentrification that has unfolded on a corridor-wide level along the Red/Purple, Blue, Gold, and Green lines over our 21 year observation period.[4] We observe no net loss of Lowest, Low, or Lower-Middle Income populations in any station area, and in fact usually slow increases in these income categories' populations, consistent with the results of our statistical models that indicate no significant and differential positive effects of rail stations on these categories' out-mobility rates. In addition to the specific evidence of displacement we find with our statistical models, we theorize that our descriptive statistics indicate the phenomenon of *exclusionary displacement* in these station areas, where existing lower-income residents are not directly displaced but new ones may not be able to afford to enter (Marcuse, 1985).

While we find context-specific displacement effects of rail stations, our body of evidence regarding the general potential for rail stations to cause significant displacement is mixed, which is consistent with the existing literature (Rayle, 2015; Zuk et al., 2015; Zuk et al., 2017). Despite our fine-grained dataset, measurement strategy, and control area methodology, we can neither fully reject nor accept our hypothesis that rail stations significantly and differentially displace lower-income households, given our inconsistent statistical modeling results and the potential for exclusionary displacement we raise above. We underscore the need for future research to continue uncovering the link between rail transit, gentrification, and displacement.

We believe a critical lens through which future research should view this nexus is housing tenure, *i.e.* homeowners versus renters. Earlier in this report, we present national-level evidence that renters have a very high annual mobility rate relative to homeowners. In our own statistical models, our results suggest that Middle and Upper Income households (>80% AMI) in station areas may have the largest increases in out-mobility rates. It is likely that this income category – and our other three income categories – is largely comprised of renters, given that the renter-occupied housing unit rate for Los Angeles County is around 54.3%.[5] Moreover, of all

[4] Because we use relative measures of income that are adjusted on an annual basis (*i.e.*, percentage of AMI), we can make credible claims about gentrification based on composition.

[5] Based on U.S. Census 2012-2016 owner-occupied housing rate of 45.7% for Los Angeles County, Table SEX255216, available from https://www.census.gov/quickfacts/fact/table/losangelescountycalifornia/SEX255216. Retrieved June 11, 2018.

of our income categories, households in this category should be most able to cover any costs associated with moving. They may also have more extensive social networks to assist in finding other housing options (Weisbrod & Vidal, 1981). Thus, although renters in lower-income categories may experience the most pressure on their incomes, renters in higher-income categories may actually be better able to move out and thereby exhibit evidence of displacement.

End Notes

[i] Households' zip codes, when present in the tax filing data from the FTB, came in either 5-digit or 9-digit format. For confidentiality reasons, the FTB provided households' zip codes at the 9-digit level in a given year of the dataset if there were at least 10 households that filed taxes under that 9-digit zip code; otherwise, the FTB provided household data at the 5-digit level. To geocode the locations of households with 9-digit zip codes attached to their tax files, we match the 9-digit zip codes with latitude and longitude coordinates using conversion files from Geolytics, Inc., a private provider of location data. Given that 9-digit zip codes' geographic locations may shift over time, we use Geolytics data for as many years as available, *i.e.*, the years 2000, 2004, 2007, 2009, 2012, 2013, and 2014. For households whose 9-digit zip codes are missing from Geolytics and for households whose tax files have 5-digit zip codes, we use the latitude and longitude of the centroid of the 5-digit zip code containing each such household. Households missing zip-code information are not included in our analyses.

[ii] As we alluded to in Section 2.3, the station and control areas comprising the sample used in our statistical models have different population levels (see Appendix B). Because we are estimating the rail station effect on a station area's out-mobility rate for an "average" station in the L.A. Metro rail system or in a particular rail corridor, these differences in population levels – if not controlled for – may unduly influence our estimates.

We consider four different weights to address this issue. First, we try weighting by the baseline population in each neighborhood (see Appendix B), which controls for different areas' population levels in each year and thereby isolates out-mobility from underlying population growth. Second, we try weighting by the neighborhood population that we are able to geocode at the 9-digit zip code level in both years t and $t + 1$, which favors areas with high numbers of precisely geocoded households in their computed out-mobility rates. Third, we try weighting by the share of a station or control area's out-mobility rate derived from households with 9-digit zip codes geocoded in years t and $t + 1$, which favors neighborhoods with the most precisely computed out-mobility rates. Fourth, we try weighting by the quotient of the first and second weights, which is in effect a probability weight based on the 9-digit zip code coverage in a neighborhood.

Based on preliminary analytical work, we choose the baseline population level weight (weight 1) as it produces the most statistically significant results in the largest amount of cases, is the easiest to interpret, and avoids reliance on a geocoding-derived weight. The remainder of estimations in this paper use this baseline population weight.

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Appendix

Appendix A. Control Neighborhood Location

Figure A1. Map of Los Angeles City Neighborhoods and Red/Purple Subway Line Stations and Control Areas. Each red and blue dot represents a station area with radius of one-half mile, centered about a Red/Purple Line station or control intersection. Note dots are not to scale.

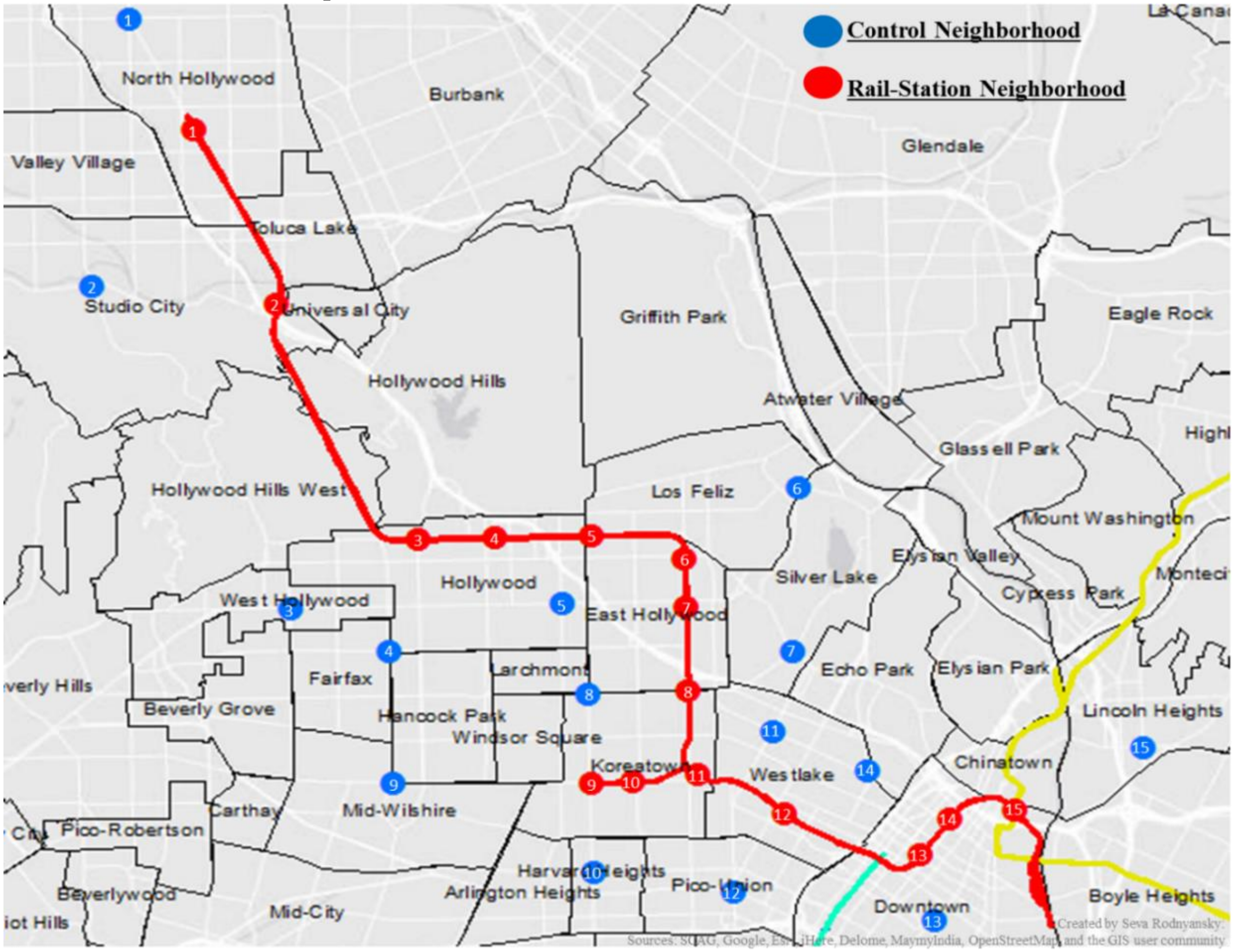
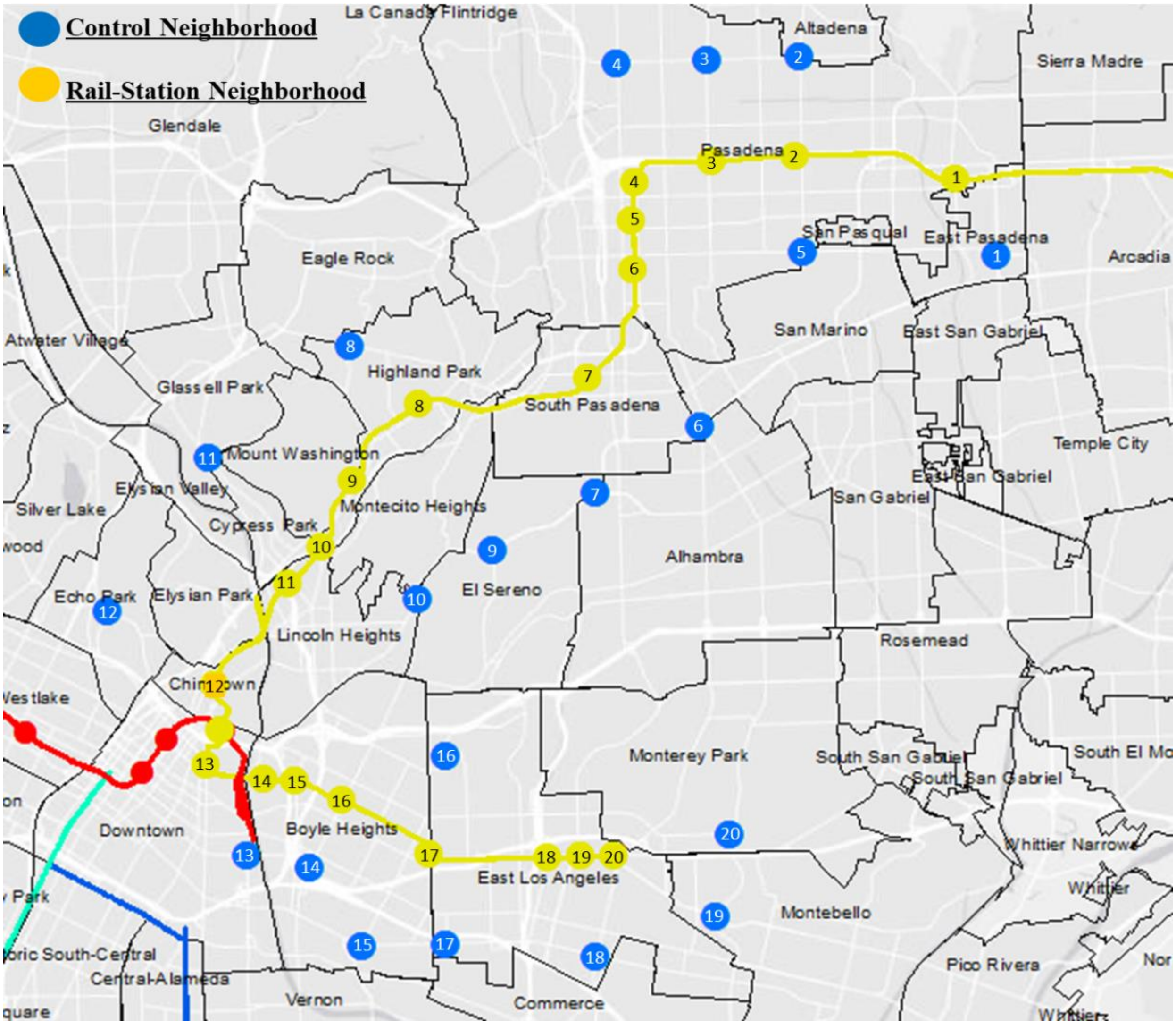
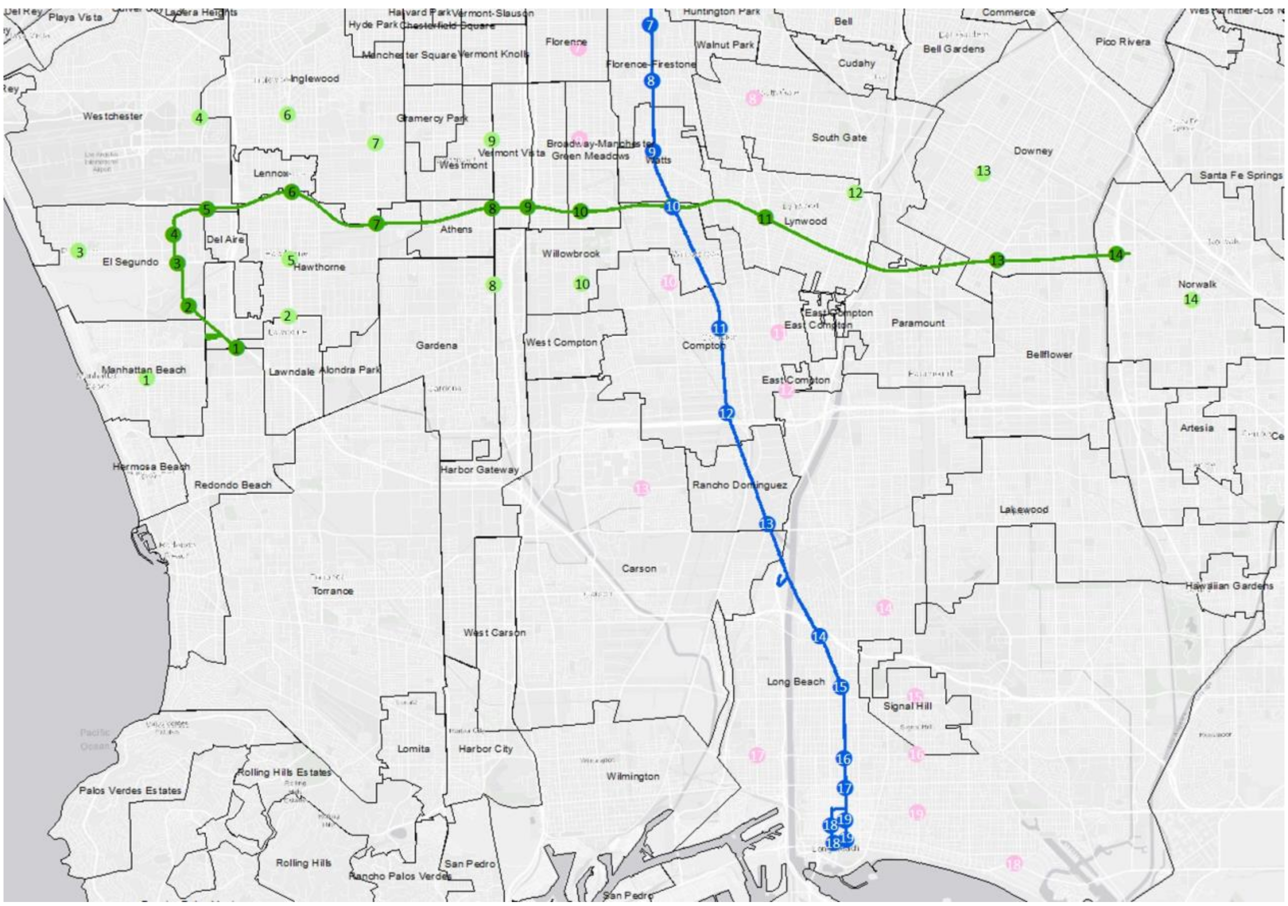


Figure A2. Map of Los Angeles City Neighborhoods and Gold Light Rail Line Stations and Controls. Each gold and blue dot represents a station area with radius of one-half mile, centered about a Gold Line station or control intersection. Note dots are not to scale.



Figures A3-4. Map Expo, Green, and Blue Line Stations and Controls. Each dot on a line represents a station area with radius of one-half mile; each dot without a line represents a control area with radius of one-half mile. Note dots are not to scale.



Appendix B. Baseline Popultions and Out-Mobility Rates by Year

Table B1: Station and Control Area Descriptive Statistics: Distance, Year Opened, Sample Size, Out-Mobility Rate, System and Station Characteristics

#	Station Name	Control Intersection	Branch	Station Opening Year	Miles between Treatment & Control Centroid	Adjusted Baseline Population		Out-Mobility Rate	
						Treatment	Control	Treatment	Control
1	Civic Center / Grand Park	1st / 2nd / Lucas / Beverly / Glendale	Red	1993	1.0	23,600	51,044	28%	24%
2	Hollywood / Highland	Fairfax / Santa Monica	Red	2000	1.5	39,331	44,091	32%	29%
3	Hollywood / Vine	Melrose / La Brea	Red	1999	1.7	157,260	33,504	26%	22%
4	Hollywood / Western	Wilton / Santa Monica	Red	1999	0.9	49,138	47,115	33%	26%
5	North Hollywood	Victory / Lankershim / Colfax	Red	2000	1.4	165,777	170,814	26%	23%
6	Pershing Square	San Pedro / 8th St	Red	1993	0.9	57,706	23,476	25%	27%
7	Universal City / Studio City	Ventura / Laurel Canyon	Red	2000	1.9	16,852	164,454	37%	24%
8	Union Station	Main / Griffin	Red	1993	1.5	63,739	40,555	25%	16%
9	Vermont / Beverly	Western / Beverly	Red	1999	1.0	54,496	268,687	31%	22%
10	Vermont / Santa Monica	Sunset / Silver Lake	Red	1999	1.2	185,206	259,233	20%	23%
11	Vermont / Sunset	Rowena / Hyperion	Red	1999	1.4	49,617	34,053	21%	25%
12	Westlake / MacArthur Park	Venice / Hoover	Red	1993	1.0	154,375	57,761	21%	20%
13	Wilshire / Normandie	Pico / Western	Purple	1996	1.1	199,727	50,265	25%	24%
14	Wilshire / Vermont	Beverly / Rampart	Purple	1996	1.0	75,041	71,821	31%	22%
15	Wilshire / Western	Wilshire / La Brea	Purple	1996	1.0	322,613	47,540	24%	23%
16	Allen	Washington / Allen	Gold	2003	1.2	27647	34332	23%	14%
17	Atlantic	Garfield / Riggin	Gold	2009	1.4	34299	31792	13%	12%
18	Chinatown	Sunset / Echo Park	Gold	2003	1.5	82086	52408	22%	19%

19	Del Mar	California / Allen	Gold	2003	2	19620	9930	33%	24%
20	East Los Angeles Civic Center	Beverly / Garfield	Gold	2009	1.4	44668	37134	13%	16%
21	Fillmore	Huntington / Garfield / Atlantic / Los Robles	Gold	2003	2	20933	26937	31%	22%
22	Highland Park	OR: York / Avenue 50;	Gold	2003	1.1	199165	51885	23%	15%
23	Heritage Square	Heritage / Soto	Gold	2003	1.3	32242	13642	17%	21%
24	Indiana	Olympic / Ditman	Gold	2009	1.1	65874	42652	14%	14%
25	Lake	Lake / Washington	Gold	2003	1.2	34518	132792	27%	22%
26	Lincoln Heights / Cypress Park	Cypress / Division	Gold	2003	1.9	100325	29566	22%	15%
27	Little Tokyo / Arts District	7th and Santa Fe?	Gold	2009	1.2	26173	1277	26%	48%
28	Memorial Park	Fair Oaks / Washington	Gold	2003	1.4	107426	103053	28%	21%
29	Mariachi Plaza	Olympic / Lorena	Gold	2009	2.1	121708	86657	21%	22%
30	Maravilla	Olympic / Atlantic	Gold	2009	1.3	43748	37764	15%	14%
31	Pico / Aliso	Soto / 8th	Gold	2009	1.4	16382	20225	22%	17%
32	Sierra Madre Villa	California / Rosemead	Gold	2003	1	19244	17458	14%	21%
33	Soto	City Terrace / Pomeroy	Gold	2009	1.3	145377	128210	19%	19%
34	South Pasadena	Huntington / Main	Gold	2003	1.4	128678	41880	21%	19%
35	Southwest Museum	Eastern / Huntington	Gold	2003	1.8	24660	143511	19%	20%
36	Avalon	Avalon / 135th	Green	1995	1.3	33,738	24,789	16%	17%
37	Aviation / LAX	Hawthorne / El Segundo	Green	1995	1.7	8,535	326,071	16%	25%
38	Crenshaw	Crenshaw / Century	Green	1995	1.4	15,392	16,402	15%	22%
39	Douglas	Rosencrans / Hawthorne	Green	1995	1.8	7,144	50,582	11%	19%
40	El Segundo	Main / Grand in El Seg	Green	1995	1.7	339	107,375	33%	21%
41	Harbor Freeway	Vermont / Century	Green	1995	1.3	74,230	48,717	22%	16%
42	Hawthorne / Lennox	La Brea / Arbor Vitae	Green	1995	1.3	46,696	172,881	17%	18%

43	Lakewood Boulevard	Paramount / Stewart and Gray	Green	1995	1.5	38,618	37,984	14%	20%
44	Long Beach Boulevard	Atlantic / Imperial	Green	1995	1.6	147,126	48,551	25%	16%
45	Mariposa	Aviation / Arbor Vitae	Green	1995	2.1	455	8,693	30%	36%
46	Norwalk	Pioneer / Rosecrans / San Antonio	Green	1995	1.5	26,135	222,971	15%	28%
47	Redondo Beach	Sepulveda / Manhattan Beach Blvd	Green	1995	1.6	1,841	31,327	25%	15%
48	Vermont / Athens	Vermont / 135th	Green	1995	1.4	33,063	34,624	20%	17%
49	Anaheim Street	Santa Fe / Pacific Coast Highway	Blue	1990	1.6	170,293	15,479	24%	20%
50	Artesia	Long Beach Blvd / Greenleaf	Blue	1990	1.1	3,267	43,202	19%	18%
51	Compton	Compton / Bullis	Blue	1990	1.0	30,766	133,205	19%	25%
52	Del Amo	Central / University	Blue	1990	2.3	0	105,671	N/A	20%
53	Downtown Long Beach	2nd / Livingston	Blue	1990	3.1	196,051	51,277	27%	19%
54	5th Street	Cherry / 7th	Blue	1990	1.2	205,226	42,919	27%	30%
55	Florence	Avalon / 79th	Blue	1990	1.3	123,524	56,115	22%	15%
56	Firestone	Firestone / State	Blue	1990	1.8	49,267	63,606	16%	18%
57	1st Street	Cherry / 7th	Blue	1990	1.2	203,517	42,919	27%	30%
58	Grand / LATTC	Adams / Normandie	Blue	1990	1.8	52,807	114,746	28%	19%
59	Pacific Avenue	2nd / Livingston	Blue	1990	3.1	209,384	51,277	27%	19%
60	Pacific Coast Highway	Cherry / Pacific Coast Highway	Blue	1990	1.2	41,203	37,299	22%	23%
61	Pico	Venice / Hoover	Blue	1990	1.1	60,328	57,761	27%	23%
62	San Pedro Street	Jefferson / Avalon / San Pedro	Blue	1990	0.9	31,279	63,166	17%	16%
63	Slauson	Miles / Gage	Blue	1990	1.3	37,001	29,857	18%	17%
64	7th Street / Metro Center	San Pedro / 8th	Blue	1990	0.9	95,237	23,476	22%	31%
65	Vernon	Avalon / Vernon	Blue	1990	1.3	34,832	177,293	17%	23%
66	Washington	Slauson / Atlantic	Blue	1990	4.0	13,762	115,958	16%	16%
67	Wardlow	Orange / Bixby	Blue	1990	1.2	35,076	153,845	17%	20%

68	Willowbrook / Rosa Parks	Wilmington / Stockwell	Blue	1990	1.3	26,754	102,733	19%	18%
69	Willow	Willow / Cherry	Blue	1990	1.3	132,471	29,397	24%	20%
70	103rd Street / Watts Towers	Century / Avalon	Blue	1990	2.1	29,435	56,115	19%	15%
71	Culver City	Culver / Overland	Expo I	2012	1.3	84,785	40,332	20%	14%
72	Expo / Crenshaw	Vernon / Crenshaw / Leimert	Expo I	2012	1.3	34,452	25,444	15%	16%
73	Expo Park / USC	Vermont / Vernon	Expo I	2012	1.1	8,944	140,346	31%	21%
74	Expo / Vermont	Vermont / Vernon	Expo I	2012	1.0	28,071	140,346	23%	21%
75	Expo / Western	Western / Vernon	Expo I	2012	1.0	60,536	95,317	15%	18%
76	Farmdale	Adams / Arlington	Expo I	2012	1.7	32,604	149,181	13%	21%
77	Jefferson / USC	Main / Vernon	Expo I	2012	1.3	94,664	61,082	31%	17%
78	Expo / La Brea / Ethel Bradley	La Brea / Washington	Expo I	2012	1.2	169,032	45,465	20%	16%
79	La Cienega / Jefferson	Pico / Fairfax	Expo I	2012	1.8	20,746	48,864	13%	18%
80	LATTC / Ortho Institute / 23rd St	Adams / Normandie	Expo I	2012	1.5	10,562	114,746	28%	21%

Appendix C. Area Median Income by Year for the Los Angeles – Long Beach Metropolitan Statistical Area
Source: U.S. HUD

Year	Area Median Income (AMI)	80% of AMI	50% of AMI	30% of AMI
1993	$33,840	$27,072	$16,920	$10,152
1994	$36,160	$28,928	$18,080	$10,848
1995	$36,160	$28,928	$18,080	$10,848
1996	$37,520	$30,016	$18,760	$11,256
1997	$38,240	$30,592	$19,120	$11,472
1998	$39,840	$31,872	$19,920	$11,952
1999	$41,040	$32,832	$20,520	$12,312
2000	$41,680	$33,344	$20,840	$12,504
2001	$43,600	$34,880	$21,800	$13,080
2002	$44,080	$35,264	$22,040	$13,224
2003	$40,240	$32,192	$20,120	$12,072
2004	$43,360	$34,688	$21,680	$13,008
2005	$43,560	$34,848	$21,780	$13,068
2006	$44,960	$35,968	$22,480	$13,488
2007	$45,200	$36,160	$22,600	$13,560
2008	$47,840	$38,272	$23,920	$14,352
2009	$49,680	$39,744	$24,840	$14,904
2010	$50,400	$40,320	$25,200	$15,120
2011	$51,200	$40,960	$25,600	$15,360
2012	$51,840	$41,472	$25,920	$15,552
2013	$49,520	$39,616	$24,760	$14,856

Appendix D. Regression Results

Table D1: Rail Station Effects on Neighborhood Out-Mobility Rates by Timing for All Incomes, L.A. Metro Rail System-wide

*Weighted by Baseline Population in Neighborhood; Standard errors clustered by station-control area pair; * p<0.10 ** p<0.05 *** p<0.01*

	Rail Station Announcement (~4.7 years before Opening)		Rail Station Opening		5 Years after Rail Station Opened	
Model	**Difference-in-Difference**	**Fixed Effects**	**Difference-in-Difference**	**Fixed Effects**	**Difference-in-Difference**	**Fixed Effects**
Treatment	0.014		0.00912		0.011	
	(0.011)		(0.00961)		(0.008)	
Post	0.001		-0.00926		-0.015**	
	(0.008)		(0.00629)		(0.006)	
Treatment * Post	0.010	-0.001	0.0187*	0.00198	0.022**	0.010**
	(0.012)	(0.004)	(0.00949)	(0.00368)	(0.008)	(0.003)
Constant (baseline mobility rate)	0.208***	0.299***	0.215***	0.299***	0.216**	0.299**
	(0.006)	(0.004)	(0.00712)	(0.00387)	(0.006)	(0.004)
Year fixed effect	No	Yes	No	Yes	No	Yes
Neighborhood fixed effect	No	Yes	No	Yes	No	Yes
Adjusted R^2	0.050	0.872	0.054	0.872	0.061	0.874
AIC	418.561	-15520.138	-9431.0	-15521.4	-9450.78	-15569.174
BIC	394.563	-15400.144	-9407.0	-15401.5	-9426.78	-15449.180
F-test	4.84	37.51	5.11	36.53	8.58	8.43
Prob > F	0.0038	0	0.0028	0	0.0001	0.0048
Number of Observations	2980	2980	2980	2980	2980	2980

Table D2: Panel FE Model Rail Station Effects on Neighborhood Out-Mobility Rates by Timing and Rail Corridor

Model types: Fixed Effects; Weighted by Baseline Population in Neighborhood; Standard errors clustered by station-control area pair

** p<0.10 ** p<0.05 *** p<0.01*

Notes: We exclude rail corridors whose key years (opening, announcement, or 5 years after) do not fall between 1993-2013 where FTB data is available. This includes Blue Line for announcement and opening, Green line for announcement, and Expo line for 5 years after opening.

	Rail Station Announcement			**Rail Station Opening**				**5 Years After Opening**			
Rail Corridor	**Red/ Purple**	**Gold**	**Expo Phase 1**	**Red/ Purple**	**Gold**	**Green**	**Expo Phase 1**	**Red/ Purple**	**Gold**	**Green**	**Blue**
Treatment * Post	-0.010	0.001	0.010**	0.011*	0.001	-0.023	0.006	0.010***	0.011*	-0.017*	0.035**
	(0.011)	(0.004)	(0.004)	(0.005)	(0.003)	(0.016)	(0.007)	(0.003)	(0.006)	(-0.008)	(0.014)
Constant (baseline mobility rate)	0.317***	0.279***	0.289***	0.311***	0.279***	0.305***	0.289***	0.312***	0.279***	0.305***	0.302***
	(0.007)	(0.008)	(0.009)	(0.006)	(0.008)	(0.007)	(0.009)	(0.006)	(0.007)	(0.008	(0.008)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Neighborhood fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.702	0.730	0.730	0.705	0.730	0.769	0.728	0.706	0.732	0.770	0.699
AIC	-10987.66	-13461	-5984	-11007.5	-13460.9	-7901.9	-5976.3	-11016.7	-13483.9	-7909.16	-12939.1
BIC	-10900.91	-13346	-5937	-10920.7	-13346.1	-7835.7	-5928.8	-10929.9	-13369	-7842.95	-12818.2
F-test	0.82	0.09	6.31	3.99	0.07	2.00	0.79	8.76	3.59	3.84	5.80
Prob > F	0.379	0.7678	0.033	0.064	0.789	0.183	0.3981	0.010	0.074	0.074	0.025
Number of Observations	2400	3120	1440	2400	3120	1840	1440	2400	3120	1840	3119

Table D3: DID Model Rail Station Effects on Neighborhood Out-Mobility Rates by Timing and Rail Corridor

Model types: Difference-in-Difference; Weighted by Baseline Population in Neighborhood; Standard errors clustered by station-control area pair

** p<0.10 ** p<0.05 *** p<0.01*

Notes: We exclude rail corridors whose key years (opening, announcement, or 5 years after) do not fall between 1993-2013 where FTB data is available. This includes Blue Line for announcement and opening, Green line for announcement, and Expo line for 5 years after opening.

	Rail Station Announcement			**Rail Station Opening**				**5 Years After Opening**			
Rail Corridor	**Red/ Purple**	**Gold**	**Expo Phase 1**	**Red/ Purple**	**Gold**	**Green**	**Expo Phase 1**	**Red/ Purple**	**Gold**	**Green**	**Blue**
Treatment	0.029**	0.016	0.013	0.018	0.015	0.004	0.017	0.018	0.016*	-0.010	0.013
	(0.003)	(0.010)	(0.025)	(0.014)	(0.010)	(0.035)	(0.025)	(0.012)	(0.009)	(0.032)	(0.017)
Post	-0.096**	-0.032**	-0.028**	-0.041**	-0.020**	-0.088**	-0.030**	-0.026***	-0.007	-0.050***	-0.089***
	(0.007)	(0.005)	(0.003)	(0.004)	(0.006)	(0.011)	(0.004)	(0.005)	(0.008)	(0.006)	(0.012)
Treatment * Post	-0.007	0.007	0.010*	0.007	0.013*	-0.025	0.005	0.008	0.023**	-0.012	0.033**
	(0.012)	(0.006)	(0.005)	(0.009)	(0.006)	(0.019)	(0.007)	(0.008)	(0.009)	(0.012)	(0.014)
Constant (baseline mobility rate)	0.322**	0.208**	0.200**	0.259**	0.197**	0.301**	0.191**	0.242***	0.191***	0.256***	0.282***
	(0.005)	(0.009)	(0.010)	(0.004)	(0.008)	(0.020)	(0.009)	(0.004)	(0.008)	(0.017)	(0.015)
Year fixed effect	No	No	No	No	No	No	No	No	No	No	No
Neighborhood fixed effect	No	No	No	No	No	No	No	No	No	No	No
Adjusted R^2	0.122	0.112	0.068	0.195	0.056	0.296	0.033	0.132	0.046	0.242	0.344
AIC	-2199.72	-2555.30	-1121.49	-2252.11	-2507.95	-1534.01	-1108.51	-2206.51	-2499.55	-1500.37	-2773.54
BIC	-2182.13	-2536.66	-1105.95	-2234.55	-2489.31	-1517.48	-1092.96	-2188.92	-2480.91	-1483.85	-2754.9
F-test	697.09	13.76	26.83	41.17	6	42.77	16.83	10.59	4.53	46.77	54.87
Prob > F	0	0.0001	0.0001	0	0.0047	0	0	0.0005	0.0147	0	0
Number of Observations	600	780	360	600	780	460	360	600	780	460	780

Table D4: Income Category Model of Rail Station Effects on Neighborhood Out Mobility Rates, L.A. Metro Rail System-wide
*Model types: Difference-in-Difference and Fixed Effects; Weighted by Baseline Population in Neighborhood; Standard errors clustered by station-control area pair; * p<0.10 ** p<0.05 *** p<0.01*
Reference Category: Control neighborhoods with income above 80% in years where rail stations were not open (or announced or open for 5 years) in paired treatment neighborhoods

	Rail Station Announcement (~4.7 years pre-opening)		Rail Station Opening		Five Years After Opening	
Model	**Difference-in-Difference**	**Fixed Effects**	**Difference-in-Difference**	**Fixed Effects**	**Difference-in-Difference**	**Fixed Effects**
Income = <30% AMI	0.046***	0.045***	0.042***	0.044***	0.043**	0.042**
	(0.007)	(0.002)	(0.007)	(0.002)	(0.006)	(0.003)
Income = 30-50% AMI	0.040***	0.040***	0.036***	0.039***	0.038**	0.037**
	(0.007)	(0.002)	(0.007)	(0.002)	(0.006)	(0.002)
Income = 50-80% AMI	0.026***	0.028***	0.023***	0.027***	0.024**	0.026**
	(0.007)	(0.002)	(0.006)	(0.002)	(0.005)	(0.002)
Treatment * Income = <30% AMI	0.013		0.010		0.008	
	(0.013)		(0.012)		(0.009)	
Treatment * Income = 30-50% AMI	0.007		0.003		0.004	
	(0.011)		(0.010)		(0.009)	
Treatment * Income = 50-80% AMI	0.011		0.005		0.007	
	(0.010)		(0.009)		(0.008)	
Treatment * Income = >80% AMI	0.027**		0.014		0.020*	
	(0.010)		(0.010)		(0.009)	
Post * Income = <30% AMI	0.000		-0.010		-0.019**	
	(0.008)		(0.007)		(0.006)	
Post * Income = 30-50% AMI	0.001		-0.009		-0.017*	
	(0.008)		(0.007)		(0.007)	
Post * Income = 50-80% AMI	0.005		-0.004		-0.010	
	(0.008)		(0.007)		(0.006)	

Post * Income = >80% AMI	0.007		-0.007		-0.011*	
	(0.010)		(0.008)		(0.007)	
Treatment * Post * Income = <30% AMI	0.004	-0.008*	0.009	-0.005	0.015*	0.003
	(0.014)	(0.004)	(0.012)	(0.004)	(0.009)	(0.004)
Treatment * Post * Income = 30-50% AMI	0.009	-0.007*	0.016	-0.004	0.020*	0.003
	(0.013)	(0.004)	(0.010)	(0.003)	(0.008)	(0.004)
Treatment * Post * Income = 50-80% AMI	0.012	0.001	0.023**	0.005	0.026**	0.014**
	(0.012)	(0.004)	(0.009)	(0.004)	(0.008)	(0.004)
Treatment * Post * Income = >80% AMI	0.013	0.015***	0.031***	0.018***	0.031**	0.027**
	(0.012)	(0.005)	(0.009)	(0.005)	(0.007)	(0.004)
Constant (baseline mobility rate)	0.176***	0.269***	0.187***	0.269***	0.188**	0.271**
	(0.009)	(0.004)	(0.010)	(0.004)	(0.008)	(0.004)
Year fixed effect	No	Yes	No	Yes	No	Yes
Neighborhood fixed effect	No	Yes	No	Yes	No	Yes
Adjusted R^2	0.090	0.796	0.095	0.796	0.102	0.798
AIC	-36130.878	-54096.601	-36198.044	-54092.795	-36279.656	-54177.742
BIC	-36012.704	-53904.568	-36079.870	-53900.762	-36161.481	-53985.709
F-test	13.69	69.61	17.65	74.17	18.94	55.75
Prob > F	0	0	0	0	0	0
Number of Observations	11919	11919	11919	11919	11919	11919

Table D5: Upon Station Announcement, Income Category Model of Rail Station Effects on Neighborhood Out Mobility Rates, by Rail Corridor
*Model types: Difference-in-Difference and Fixed Effects; Weighted by Baseline Population in Neighborhood; Standard errors clustered by station-control area pair; * p<0.10 ** p<0.05 *** p<0.01*
Reference Category: Control neighborhoods with income above 80% in years where rail stations were not Announced in paired treatment neighborhoods
Notes: Blue Line excluded from this analysis, since it opened in 1990, prior to the earliest year of the FTB dataset available. We exclude Green Line from the announcement analysis, since the Green Line was announced in 1991, prior to FTB data availability.

Rail Station Announcement

Rail Corridor	**Red/Purple**		**Gold**		**Expo Phase I**	
Model	**Difference-in-Difference**	**Fixed Effects**	**Difference-in-Difference**	**Fixed Effects**	**Difference-in-Difference**	**Fixed Effects**
Income = <30% AMI	0.030**	0.033**	0.035**	0.037**	0.068**	0.059**
	(0.002)	(0.003)	(0.005)	(0.005)	(0.008)	(0.005)
Income = 30-50% AMI	0.031**	0.032**	0.033**	0.035**	0.057**	0.048**
	(0.009)	(0.005)	(0.005)	(0.005)	(0.009)	(0.006)
Income = 50-80% AMI	0.026**	0.027**	0.021**	0.026**	0.039**	0.030**
	(0.003)	(0.006)	(0.004)	(0.004)	(0.010)	(0.007)
Treatment * Income = <30% AMI	0.029**		0.009		0.024	
	(0.003)		(0.010)		(0.031)	
Treatment * Income = 30-50% AMI	0.014		0.006		0.012	
	(0.015)		(0.011)		(0.025)	
Treatment * Income = 50-80% AMI	0.012*		0.018		0.003	
	(0.005)		(0.011)		(0.020)	
Treatment * Income = >80% AMI	0.045**		0.040**		0.013	
	(0.006)		(0.010)		(0.021)	
Post * Income = <30% AMI	-0.098**		-0.028**		-0.029**	
	(0.005)		(0.005)		(0.003)	
Post * Income = 30-50% AMI	-0.101**		-0.028**		-0.026**	
	(0.014)		(0.006)		(0.004)	
Post * Income = 50-80% AMI	-0.100**		-0.028**		-0.026**	
	(0.007)		(0.006)		(0.005)	
Post * Income = >80% AMI	-0.098**		-0.032**		-0.024**	
	(0.006)		(0.006)		(0.004)	
Treatment * Post * Income = <30% AMI	-0.015	-0.018	-0.005	-0.011*	0.013*	0.014*

	(0.011)	(0.011)	(0.006)	(0.005)	(0.005)	(0.006)
Treatment * Post * Income = 30-50% AMI	-0.002	-0.019	0.003	-0.004	0.005	0.003
	(0.020)	(0.011)	(0.005)	(0.004)	(0.006)	(0.005)
Treatment * Post * Income = 50-80% AMI	0.008	-0.013	0.007	0.005	0.011	0.008*
	(0.013)	(0.011)	(0.006)	(0.004)	(0.007)	(0.004)
Treatment * Post * Income = >80% AMI	0.000	0.012	0.016*	0.019**	0.007	0.015
	(0.013)	(0.011)	(0.009)	(0.006)	(0.008)	(0.009)
Constant (baseline mobility rate)	0.303**	0.293**	0.183**	0.254**	0.154**	0.251**
	(0.003)	(0.009)	(0.009)	(0.009)	(0.012)	(0.011)
Year fixed effect	No	Yes	No	Yes	No	Yes
Neighborhood fixed effect	No	Yes	No	Yes	No	Yes
Adjusted R^2	0.132	0.741	0.133	0.778	0.264	0.859
AIC	-8397.4	-11325.7	-9785.2	-14080.2	-4519.3	-6931.2
BIC	-8339.5	-11239.0	-9688.5	-13965.3	-4471.9	-6883.8
F-test	415.56	28.93	41.48	13.11	72.54	89.6
Prob > F	0	0	0	0	0	0
Number of Observations	2400	2400	3120	3120	1440	1440
Potential Degrees of Freedom Issue	Yes				Yes	

Table D6: Coincident with Station Openings, Income Category Model of Rail Station Effects on Neighborhood Out Mobility Rates, by Rail Corridor
*Model types: Difference-in-Difference and Fixed Effects; Weighted by Baseline Population in Neighborhood; Standard errors clustered by station-control area pair; * p<0.10 ** p<0.05 *** p<0.01*
Reference Category: Control neighborhoods with income above 80% in years where rail stations were not Open in paired treatment neighborhoods
Notes: Blue Line excluded from this analysis, since it opened in 1990, prior to the earliest year of the FTB dataset available.

Rail Station Opening

Rail Corridor	Red/Purple		Gold		Green		Expo Phase I	
Model	**Difference-in-Difference**	**Fixed Effects**	**Difference-in-Difference**	**Fixed Effects**	**Difference-in-Difference**	**Fixed Effects**	**Difference-in-Difference**	**Fixed Effects**
Income = <30% AMI	0.042**	0.033**	0.036**	0.033**	0.045**	0.046**	0.067**	0.059**
	(0.006)	(0.003)	(0.005)	(0.005)	(0.008)	(0.004)	(0.008)	(0.005)
Income = 30-50% AMI	0.038**	0.033**	0.033**	0.031**	0.048**	0.041**	0.057**	0.046**
	(0.008)	(0.004)	(0.005)	(0.005)	(0.007)	(0.004)	(0.010)	(0.005)
Income = 50-80% AMI	0.022*	0.025**	0.021**	0.023**	0.023*	0.026**	0.040**	0.029**
	(0.008)	(0.005)	(0.004)	(0.004)	(0.012)	(0.004)	(0.010)	(0.006)
Treatment * Income = <30% AMI	0.012		0.005		0.012		0.028	
	(0.015)		(0.009)		(0.035)		(0.032)	
Treatment * Income = 30-50% AMI	0.012		0.004		-0.005		0.014	
	(0.017)		(0.010)		(0.033)		(0.024)	
Treatment * Income = 50-80% AMI	0.011		0.018		0.000		0.007	
	(0.014)		(0.011)		(0.040)		(0.019)	
Treatment * Income = >80% AMI	0.027*		0.041**		-0.031		0.016	
	(0.013)		(0.010)		(0.037)		(0.021)	
Post * Income = <30% AMI	-0.050**		-0.015*		-0.091**		-0.028**	
	(0.005)		(0.006)		(0.010)		(0.007)	
Post * Income = 30-50% AMI	-0.046**		-0.016*		-0.097**		-0.034**	
	(0.005)		(0.006)		(0.009)		(0.003)	
Post * Income = 50-80% AMI	-0.031**		-0.014*		-0.084**		-0.035**	
	(0.005)		(0.007)		(0.014)		(0.006)	

Post * Income = >80% AMI	-0.032**		-0.021**		-0.085**		-0.023**	
	(0.005)		(0.006)		(0.014)		(0.007)	
Treatment * Post * Income = <30% AMI	0.006	0.003	0.001	-0.009*	-0.026	-0.017	0.008	0.013*
	(0.010)	(0.006)	(0.006)	(0.005)	(0.019)	(0.017)	(0.009)	(0.007)
Treatment * Post * Income = 30-50% AMI	0.003	0.002	0.008	-0.005	-0.016	-0.023	0.000	-0.006
	(0.011)	(0.005)	(0.005)	(0.003)	(0.020)	(0.018)	(0.008)	(0.006)
Treatment * Post * Income = 50-80% AMI	0.012	0.014*	0.011*	0.003	-0.032	-0.028	0.005	-0.003
	(0.008)	(0.005)	(0.006)	(0.004)	(0.024)	(0.017)	(0.008)	(0.008)
Treatment * Post * Income = >80% AMI	0.023*	0.038**	0.020*	0.015*	-0.009	-0.024	0.006	0.016
	(0.009)	(0.007)	(0.011)	(0.007)	(0.020)	(0.017)	(0.009)	(0.011)
Constant (baseline mobility rate)	0.232**	0.286**	0.173**	0.256**	0.274**	0.278**	0.145**	0.251**
	(0.003)	(0.008)	(0.009)	(0.009)	(0.022)	(0.006)	(0.012)	(0.011)
Year fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Neighborhood fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Adjusted R^2	0.202	0.749	0.087	0.773	0.354	0.866	0.241	0.857
AIC	-8588.6	-11407	-9623.1	-14012	-5982.3	-8904.9	-4474.2	-6908.7
BIC	-8501.8	-11320	-9526.3	-13897	-5916.1	-8838.7	-4426.7	-6861.3
F-test		29.22	192.71	11.24		46.4	302.71	124.15
Prob > F		0	0	0		0	0	0
Number of Observations	2400	2400	3120	3120	1840	1840	1440	1440
Potential Degrees of Freedom Issue	Yes				Yes		Yes	

Table D7: Five Years After Station Openings, Income Category Model of Rail Station Effects on Neighborhood Out Mobility Rates, by Rail Corridor
*Model types: Difference-in-Difference and Fixed Effects; Weighted by Baseline Population in Neighborhood; Standard errors clustered by station-control area pair; * p<0.10 ** p<0.05 *** p<0.01*
Reference Category: Control neighborhoods with income above 80% in years where rail stations were not observed Five Years After in paired treatment neighborhoods
Notes: Expo Line excluded from this analysis, as it opened within five years of the end of our observation period

5 Years After Rail Station Opening

Rail Corridor	**Red/Purple**		**Gold**		**Green**		**Blue**	
Model	**Difference-in-Difference**	**Fixed Effects**	**Difference-in-Difference**	**Fixed Effects**	**Difference-in-Difference**	**Fixed Effects**	**Difference-in-Difference**	**Fixed Effects**
Income = <30% AMI	0.038***	0.030***	0.040***	0.029***	0.042***	0.047***	0.079***	0.060***
	(0.006)	(0.003)	(0.005)	(0.005)	(0.004)	(0.005)	(0.016)	(0.003)
Income = 30-50% AMI	0.033***	0.029***	0.037***	0.029***	0.040***	0.042***	0.064***	0.051***
	(0.007)	(0.003)	(0.005)	(0.005)	(0.006)	(0.004)	(0.014)	(0.004)
Income = 50-80% AMI	0.022***	0.022***	0.024***	0.022***	0.021**	0.026***	0.033***	0.035***
	(0.007)	(0.004)	(0.004)	(0.004)	(0.007)	(0.004)	(0.010)	(0.004)
Treatment * Income = <30% AMI	0.011		0.004		0.001		-0.003	
	(0.012)		(0.009)		(0.031)		(0.019)	
Treatment * Income = 30-50% AMI	0.012		0.004		-0.015		0.013	
	(0.015)		(0.010)		(0.029)		(0.017)	
Treatment * Income = 50-80% AMI	0.013		0.019*		-0.019		0.021	
	(0.014)		(0.010)		(0.034)		(0.015)	
Treatment * Income = >80% AMI	0.032***		0.045***		-0.042		0.031**	
	(0.011)		(0.010)		(0.035)		(0.011)	
Post * Income = <30% AMI	-0.036***		-0.003		-0.053***		-0.103***	
	(0.006)		(0.008)		(0.004)		(0.014)	
Post * Income = 30-50% AMI	-0.029***		-0.005		-0.055***		-0.096***	
	(0.008)		(0.009)		(0.005)		(0.013)	
Post * Income = 50-80% AMI	-0.016**		0.001		-0.044***		-0.076***	
	(0.006)		(0.009)		(0.008)		(0.011)	

Post * Income = >80% AMI	-0.016***		-0.007		-0.049***		-0.070***	
	(0.005)		(0.007)		(0.008)		(0.010)	
Treatment * Post * Income = <30% AMI	0.008	0.001	0.011	-0.002	-0.018	-0.015	0.040**	0.026*
	(0.008)	(0.003)	(0.008)	(0.004)	(0.012)	(0.009)	(0.016)	(0.015)
Treatment * Post * Income = 30-50% AMI	0.003	-0.000	0.021**	0.004	-0.005	-0.016	0.026*	0.027*
	(0.010)	(0.004)	(0.009)	(0.006)	(0.012)	(0.009)	(0.014)	(0.015)
Treatment * Post * Income = 50-80% AMI	0.012	0.016***	0.021**	0.015	-0.014	-0.019*	0.031**	0.040**
	(0.008)	(0.005)	(0.010)	(0.009)	(0.016)	(0.009)	(0.014)	(0.014)
Treatment * Post * Income = >80% AMI	0.020***	0.038***	0.026**	0.025**	0.003	-0.014	0.036***	0.055***
	(0.007)	(0.006)	(0.012)	(0.011)	(0.016)	(0.009)	(0.011)	(0.014)
Constant (baseline mobility rate)	0.217***	0.289***	0.164***	0.259***	0.231***	0.277***	0.232***	0.262***
	(0.004)	(0.007)	(0.008)	(0.009)	(0.018)	(0.007)	(0.009)	(0.009)
Year fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Neighborhood fixed effect	No	Yes	No	Yes	No	Yes	No	Yes
Adjusted R^2	0.153	0.752	0.080	0.773	0.306	0.866	0.342	0.788
AIC	-8445.6	-11429	-9600.7	-14009	-5852.0	-8907.9	-10464	-14043
BIC	-8358.8	-11342	-9504.0	-13894	-5785.8	-8841.6	-10367	-13916
F-test	31.58	29.33	80.42	18.13	31.53	21.6	116.71	80.24
Prob > F	0	0	0	0	0	0	0	0
Number of Observations	2400	2400	3120	3120	1840	1840	3119	3119