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Special Issue

Who's Moving In? A Longitudinal Analysis of Home Purchase Loan Borrowers in New Transit Neighborhoods

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This article examines the characteristics of residents moving into new rail transit neighborhoods using longitudinal, individual-level data from the Housing Mortgage Disclosure Act. To disentangle the role of transit from other neighborhood amenities that may give rise to shifts in the socioeconomic or demographic profile of homebuyers, an exploratory text analysis is first performed on property advertisements in transit-adjacent neighborhoods. This informs the creation of variables for our models that estimate the probability of an applicant applying for a loan by race and income, and highlights where light rail is most prominently advertised as an amenity. We do not find that the announcement of a new light rail line significantly alters the income profile of loan applicants. Rather, proximity to the center city is a more important determinant in attracting higher income applicants. We do find that the announcement of the transit line is significant in explaining changes in the racial profile of applicants. Postannouncement, White applicants are significantly more likely to apply for loans in transit-adjacent neighborhoods, while Blacks are significantly less likely to. As for other amenities, the walkability of a neighborhood is significant in predicting where White applicants are more likely to apply for home purchase loans.

Introduction

The placement of new rail transit stations is often thought to spur gentrification in surrounding neighborhoods and potentially lead to the displacement of lower income residents as property values rise and neighborhoods change (Rayle 2015; Zuk, Bierbaum, Chapple, Gorska, and Loukaitou-Sideris 2018). The literature on the relationship between transit stations and neighborhood change has yielded mixed results—some neighborhoods do experience gentrification-type changes, but many do not (Kahn 2007; Pollack, Bluestone, and Billingham 2010;

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Bardaka, Delgado, and Florax 2018; Nilsson and Delmelle 2018; Baker and Lee 2019). When neighborhoods do change, they tend to be located in faster growing cities and they are more likely to occur near stations featuring associated transit-oriented development (TOD), or mixed-use, walkable environments as compared to park-and-ride-type stations (Kahn 2007; Nilsson and Delmelle 2018). Given that walkable, mixed-use environments have seen a boost in popularity, and property values nationwide, particularly in the wake of the recovery period from the great recession (Sohn, Moudon, and Lee 2012; Xu, Yu, Lee, and Frank 2018), the role of proximity to the transit station itself, disentangled from other neighborhood amenities in spurring neighborhood sociodemographic changes is not well understood.

Our point of departure from the literature in this article is to examine characteristics of those moving into new transit neighborhoods using longitudinal, individual-level data from the Housing Mortgage Disclosure Act (HMDA) in a case study on a new light rail line in Charlotte, North Carolina. To disentangle the role of transit from other neighborhood amenities that may give rise to shifts in the socioeconomic or demographic profile of homebuyers, we first perform an exploratory text analysis on property advertisements in transit-adjacent neighborhoods obtained from Zillow. The text analysis highlights other important neighborhood amenities marketed to attract homebuyers including restaurants, walkability, and proximity to downtown. This analysis then informs the creation of spatial variables included in our models. We next model the likelihood that a homebuyer is White, Black, low-moderate or middle-upper income. Our results suggest that with regards to applicant income, proximity to the center city is a more important determinant than proximity to rail transit. In fact, we find no significant effect of the announcement of a new light rail line on the probability of applicants of different income classes applying for homes in nearby neighborhoods. However, when it comes to applicant race, the announcement of the new transit line has a significant effect on where people of different races apply for home purchase loans. Other neighborhood amenities such as walkability only had an impact on the probability of where White applicants applied for loans and high concentrations of craft breweries had a negative effect on the probability of attracting Black homebuyers.

This article contributes to our understanding of the role that new transit investments play in shaping the residential decisions that give rise to observed changes at the neighborhood scale. It also introduces a unique collection of data and a methodological workflow that contributes more broadly to neighborhood dynamics research. The remaining structure of this article is as follows: the second section provides a background on rail transit investments and neighborhood change. The third section describes the study area and the data used. The empirical approach is described in section 4, which is followed by a presentation and discussion of the results in section 5. The sixth section provides some concluding remarks and directions for future work.

Background

Whether or not a neighborhood undergoes changes in its socioeconomic profile can be explained by an interplay of supply and demand forces at both the metropolitan and neighborhood scales. A strong regional economy and an influx of new residents give rise to a set of population characteristics that shape the demand side of housing markets, while new housing construction and the existing stock of housing with a given set of traits form the supply side of the equation (Grigsby et al. 1987; Galster and Tatian 2009). Aside from housing itself, the demand for a particular neighborhood is also shaped by attributes that serve to make it more attractive including nearby amenities, proximity to employment, and walkability (Tiebout 1956). Traditional urban

economic theories predict that demand for neighborhoods and housing rest on a tradeoff between accessibility and lot size; those more willing to pay for higher commuting costs will opt to live on larger lots away from center cities (Alonso 1964; Muth 1969). However, more recent scholarship has suggested that proximity to urban amenities and more walkable environments are increasingly desirable traits, placing renewed demand on more accessible, central city locations. This trend has been particularly acute in the recovery period following the Great Recession (Couture and Handbury 2015; Kuang 2017; Myers and Gearin 2001). Beyond these supply and demand mechanisms, the likelihood that a neighborhood will undergo socioeconomic changes and, in particular, ascent, is also driven by other external factors including government investments in new infrastructure, the marketing of neighborhoods by realtors to spur interest, and the actions of local residents to resist changes (Zuk et al. 2018).

The extent to which new transit stations serve as a desirable amenity capable of invigorating demand for a neighborhood is an unsettled issue in the literature. When demand for housing across a metropolitan area (MSA) is high, the placement of a new rail line and associated changes in zoning policies to encourage mixed-used economic development around stations serves as a strong signal to developers on where to locate new projects. The outcome of these decisions has tended to result in the development of higher end multifamily dwellings which attract a more highly educated, childless resident willing to pay a premium for the new transit station and associated new commercial developments (Bowes and Ihlanfeldt 2001; Bhattacharjee and Goetz 2016). Studies on neighborhood changes in transit-adjacent neighborhoods have therefore begun to converge on the types of changes that are more likely to occur nearby including an increase in multifamily housing, the share of White residents and those with a college degree, a rise in median household income, and a decline in the share of children (Kahn 2007; Pollack, Bluestone, and Billingham 2010; Barton and Gibbons 2017; Dong 2017; Wang and Woo 2017; Bardaka, Delgado, and Florax 2018; Nilsson and Delmelle 2018; Hess 2020).

It is important to note that these changes are far from uniform across all cities and stations as they have proven to be highly context dependent (Kahn 2007). Some rail investments have led to little-to-no observable changes in nearby neighborhoods (Deka 2017; Dong 2017), while other cities have seen "counter-gentrification" trends near new transit stations (Baker and Lee 2019). When changes do occur in a MSA, they are more likely to accompany walk-and-ride stations and associated TODs as compared to park-and-ride stations, likely reflecting broader increases in demand for walkability and access to urban amenities (Kahn 2007; Nilsson and Delmelle 2018; Zhang, Wang, Barchers, and Lee 2018). Disentangling the importance of the transit station from the associated permissive zoning that necessarily accompanies TODs in order to enable increased density and mixed-used development is a challenge and one that has received limited attention. Duncan (2011) determined home price premiums in areas proximate to light rail stations to be contingent upon the associated permissive zoning regulations in San Diego. He also found that price premiums were confined to areas immediately surrounding stations. Higgins and Kanaroglou (2018) likewise found housing price capitalization to be dependent on the entire TOD-station area context and characterization. In Portland, Oregon, Dong (2015) examined the impact of various new urbanist neighborhood characteristics on housing market resilience and found only walkability to have a significant and positive effect on single-family housing appreciation. Access to light rail was not significant.

The literature on the relationship between transit and neighborhood change to date has overwhelmingly used aggregate, typically census data. Relatively few studies have examined the actions of individuals that give rise to observed aggregate changes (Rayle 2015). Neighborhood-scale analyses are unable to determine if changes are a product of the in-migration of new

residents, the out-migration of existing residents, or some combination of both. Delmelle and Nilsson (2020) studied characteristics of those moving out of transit neighborhoods nationwide since 1970 and found no statistically significant evidence that lower income residents have a heighted probability of leaving a neighborhood following the placement of a new rail station. Boarnet et al. (2018) used micro-data on household income and location from 1993 to 2013 to examine residential mobility into and out of areas within a half mile of a rail transit station in Los Angeles. They found in-migration rates of poorer residents to decline following the opening of a rail station. Other studies have surveyed residents of new transit or TOD neighborhoods showing that in general, newer residents have higher education levels, are younger, whiter, and have higher incomes, thus supporting the findings from aggregate-level neighborhood analyses (Lund 2006; Cao and Schoner 2013; Liu, Deng, and Le Vine 2016). These few studies, however, did not disentangle the role of transit from other potential amenities that may confound the relationship between new transit stations and neighborhood gentrification more generally.

Finally, just as walkable urban environments have seen a recent resurgence in demand in recent years, the popularity of transit neighborhoods also appears to have strengthened in the post-recessionary time period as neighborhoods in proximity to fixed transit stations have proved to be more resilient in terms of housing prices and job growth (Nelson, Stoker, and Hibberd 2019; Welch, Gehrke, and Farber 2018; Zhang et al. 2018). These very recent trends will likely have been overlooked or diminished by the use of decennial census data in examining neighborhood changes, and call for finer grained temporal analysis.

Obtaining regularly updated neighborhood change indicators is a challenge. Galster, Hayes, and Johnson (2005) evaluated a set of indicators that were updated annually, inexpensive, and embodied many of the indicators regularly used to assess neighborhood change. One data set that met these criteria was the HMDA loan application records. HMDA was enacted by the federal government in 1975 (amended in 1989) and requires almost all banks, thrifts, and mortgage companies doing business in any MSA to report information on every application for mortgage credit secured by a residence (Wyly and Hammel 2004). This includes information about the loan (e.g., loan and property type, purpose and amount), applicant information (e.g., race, sex, and income) as well as neighborhood information (e.g., census tract, demographic and socioeconomic characteristics). Research on mortgage lending using HMDA data has largely focused on modeling the probability of minority applicants being denied loans in certain neighborhoods, such as largely White and gentrifying neighborhoods (Munnell et al. 1996; Holloway 1998; Wyly and Hammel 2004; Hammel and Nilsson 2019), but it has also been used to more specifically study neighborhood change. Galster and Tatian (2009) used HMDA data indicators together with assessor's data for 1995–2005 to predict neighborhood revitalization. They found that proximity to stronger neighborhoods and inflows of higher status homebuyers are important predictors of appreciation onset in disadvantaged neighborhoods. Deng (2011) also used conventional single-family mortgage approval rates calculated from HMDA as one indicator to study neighborhood change associated with low-income housing tax credit development. In this study, we use it to examine transit-induced neighborhood changes.

Study area and data

The city of Charlotte is the county seat of Mecklenburg County and the most populous city in the state of North Carolina with a population of 859,035 in 2017, a 16.8% increase since 2010 (United States Census Bureau 2019). In 2007, the Charlotte Area Transit System opened its

first light rail line, the LYNX Blue Line which spurred $257 million in new, high density developments with another $1.58 billion in announced plans along the line, as of the opening date (Delmelle, Zhou, and Thill 2014). Research on property values in proximity to the original Blue Line demonstrated price capitalization benefits (Billings 2011). After the announcement of the city's second line, the Blue Line Extension (BLE), which extends from the city center to the UNC Charlotte's campus to the north of the city, there were high expectations that it would too spur similar developments. The BLE, which opened in March of 2018, passes through largely low-income neighborhoods, some (mostly close to the city center) of which have seen rapid housing appreciation in the last decade. The city just finalized plans for a third line, the Silver Line, which will run from the city center to the town of Matthews in the southeast part of the city with a planned opening date in 2030 (City of Charlotte 2019). As a case study city, Charlotte fits well with other cities in the United States that have recently implemented or expanded their rail transit system, most of which are rapidly growing cities with relatively few or no existing lines (e.g., Dallas, Houston, Minneapolis, Phoenix, Portland, Seattle).

As for the study time period, we chose 2006–2017. This time period includes 5 years prior to the extension's announcement in 2011, and 7 years following the announcement until its opening in early 2018. As noted by Billings (2011), the announcement of the investment, which came with the city securing federal funding for the project, is a strong signal of commitment from the city's side. Construction of new housing units by private developers started taking place along the line in the years leading up to its opening, particularly in neighborhoods near the city center (Portillo 2015, 2016a, b, c; Clasen-Kelly and Portillo 2018), and areas along the line started experiencing increasing rents and house prices (Ke and Gkritza 2019). We were unable to incorporate opening year data due to the release schedule of data from HDMA.

The first phase of our analysis includes an exploratory text analysis of property advertisements acquired from Zillow. This analysis gives a sense of how properties are marketed including where and how proximity to the light rail is featured in property advertisements. We created a database of recently sold homes from 2016 to 2018 of properties located in a neighborhood that intersected a half-mile radius of a station along the BLE. While online property transaction data have gathered some initial traction in the literature for understanding neighborhood dynamics, it has largely relied upon the more traditional, quantitative descriptions of properties or listing locations (Zook, Shelton, and Poorthuis 2017). The use of the corresponding text to understand how and where various amenities are marketed has yet to be explored.

Changes in demographic and socioeconomic characteristics of a neighborhood is the result of individuals' voluntary or involuntary decisions to move in or out. To study who is likely to move into a neighborhood (or, the revealed preferences for the housing and neighborhood characteristics described in the ads), we use publicly available annual data on home mortgage applications provided through the HMDA. These data include individual loan applications and provide pertinent information on the applicant, loan, and neighborhood. The database does not include the specific address of the home an application is for, but it does identify the census tract in which it is located. Hence, for the definition of neighborhood in this article, we use census tracts which are geographic delineations designed to be relatively homogenous in population and housing characteristics when they are first defined (Galster and Tatian 2009). Based on loan applicant characteristics reported to HMDA we can get a sense of who is attracted to the amenities offered in transit neighborhoods and who is more likely to move into certain neighborhoods. We restrict the analysis to home purchase loans of owner-occupied, one-to-four-family homes and records without edit failures. However, we do not make a distinction between prime and

subprime loans as the subprime rate following the financial crisis have been nearly nonexistent (registering well below 1% of all loans in each year including in 2006 and 2007). Finally, we use the 2000 census tract boundaries to make data comparable over time.

The selection of neighborhood amenities to include in the analysis besides access light rail transit is based on text analysis of Zillow housing ad descriptions. The technicalities of the text analysis are described in more detail in the Methodology section. Data on amenities, including proximity to local restaurants, breweries, and art galleries comes from InfoGroup's ReferenceUSA database. The historical database for the United States contains 228 million records. The database is enhanced with more than 24 million phone calls annually to verify businesses. Locations for single establishment (i.e., nonchains) full-service restaurants and art galleries were collected from this database for the years 2006–2017. Breweries have also been shown to add to the attractiveness of housing in Charlotte's center city neighborhoods (Nilsson and Reid 2019). Data on brewery locations and opening years comes from Nilsson and Reid (2019) and have been supplemented by the authors to include breweries opened in 2017. Proximity to downtown Charlotte (or the central business district [CBD]) was computed by calculating the Euclidean distance between the census tract centroid and the intersection of Trade and Tryon Street in downtown (among locals referred to as "uptown") Charlotte.

Another amenity that is often referred to in the ads is "walkability." Since detailed longitudinal street and sidewalk network data are difficult to obtain, to proxy walkability we use data from the U.S. Environmental Protection Agency's (USEPA) National Walkability Index (EPA 2019). Instead of the index itself, which provides walkability scores based on a formula that ranks selected indicators that have been demonstrated to affect the propensity of walk trips, we selected a single indicator as the others are highly time variant. Since the index is calculated based on data from 2010 and 2012, the indicator that is least likely to have changed over the study time period is the street intersection density (which only includes pedestrian-oriented intersections). A higher intersection density has shown to be highly correlated with more walk trips. Mapping the intersection density shows an expected pattern with higher values closer to center city and in town centers in the suburbs. Other suburban neighborhoods are less walkable (see Fig. 1). The EPA data is recorded at the block group level. In order to convert the index to the census tract level, the average value of the block groups falling within a census tract was used.

Methodology

To assess whether the characteristics of individuals applying for loans in transit neighborhoods are unique to those neighborhoods or if they just follow city-wide trends in similar neighborhoods, we apply a pseudo-experimental approach using difference-in-differences modeling. The dependent variables are racial and income characteristics of applicants. We formulate the following empirical model to estimate the effects of neighborhood characteristics and amenities, including whether the neighborhood is adjacent to a light rail stop, on the probability of an application *j* being made by an applicant of a certain income category or race:

$$ln\left[\frac{P}{1-P}\right] = b_0 + b_1 \mathrm{Post}_t + b_2 \mathrm{BLE}_i + b_3 \mathrm{Post}_t \times \mathrm{BLE}_i + b' X_{it} + b'' Z_{it} + e_{it} \quad (1)$$

where *i* denotes the neighborhood in which application *j* was made and *t* the year. $\mathrm{Post}_t = 1$ after the announcement of the BLE in 2011 and zero otherwise. This measures the probability of a certain

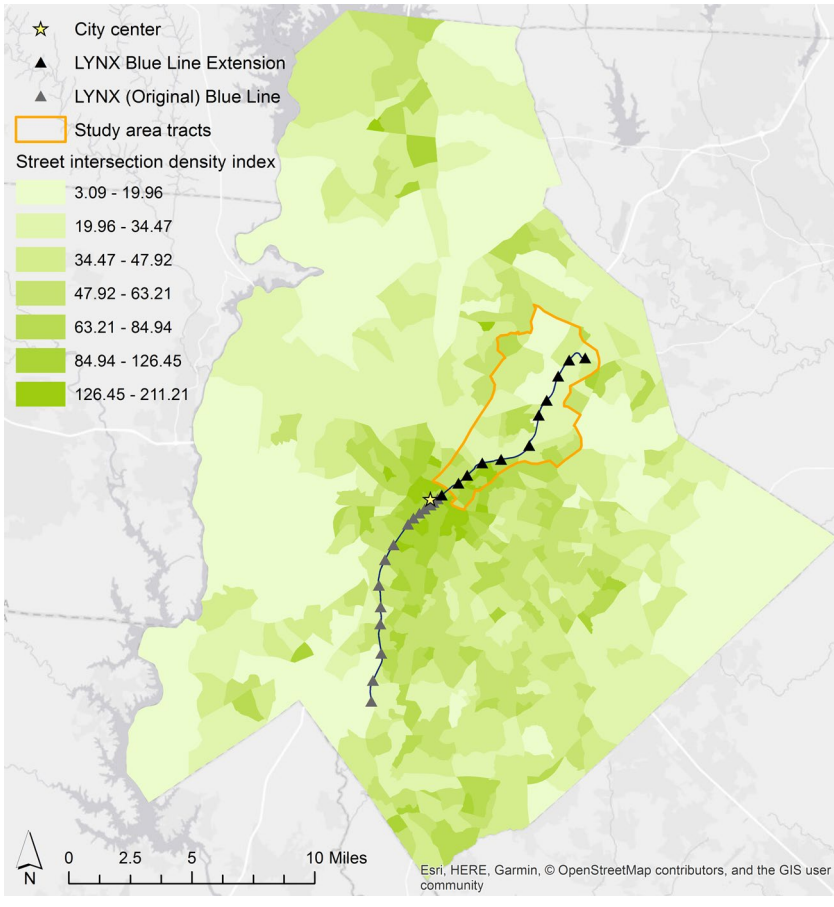

Figure 1. Map of street intersection density index.

applicant applying for a home purchase loan, after the year 2011. BLE_{it} is an indicator for whether the application was made in a BLE neighborhood. The difference-in-differences estimator is given by the interaction term $\text{Post}_t \times \text{BLE}_i$ which measures whether a certain type of applicant is more likely to apply for a home purchase loan in a BLE neighborhood after the announcement of its construction; b_3 is therefore our main coefficient of interest. X_{it} is a vector of neighborhood demographic and socioeconomic characteristics and b' is a vector of coefficients associated with each of those variables. Similarly, b'' is a vector of parameters associated with a set of neighborhood amenities (Z_{it}) as identified from the text analysis which includes walkability, proximity to the center city, and the presence of local restaurants, breweries, and art galleries. This modeling approach enables us to compare the estimated association between the income and racial profile of an individual applicant and the relative importance of different neighborhood amenities. To identify control neighborhoods, or neighborhoods in Mecklenburg County that are similar to the transit neighborhoods at the onset of the study period, we apply the K-nearest neighborhood (KNN) algorithm to find neighborhoods have minimal differences in characteristics with our transit neighborhoods in the base year 2006. Using Euclidean distance, the KNN algorithm measures the (dis)similarity between neighborhoods across a set of m characteristics according to the following function:

$$d(x,y) = \sqrt{\sum_{i=1}^{m} (x_i - y_i)^2} \tag{2}$$

Control neighborhoods are those that minimize dissimilarity with our treatment neighborhoods. Neighborhoods near the original Blue Line were not deemed appropriate as controls as they received a transit line in 2007. Similarly, first-order neighborhoods to BLE neighborhoods were excluded as candidates as there is a possibility that they could also be affected via spatial spillover effects. The final selection resulted in 12 control neighborhoods which all had a corresponding neighborhood among the transit neighborhoods. The transit and control neighborhoods are shown in Fig. 2.

The KNN algorithm was performed on nine characteristics of the neighborhoods. Descriptive statistics on these characteristics in the transit versus control neighborhoods are shown in Table 1 compared to the remaining census tracts in Mecklenburg County. The statistics in Table 1 shows that the treatment and control neighborhoods are very similar in the base year, particularly in comparison with all remaining neighborhoods in the county which are on average wealthier, with

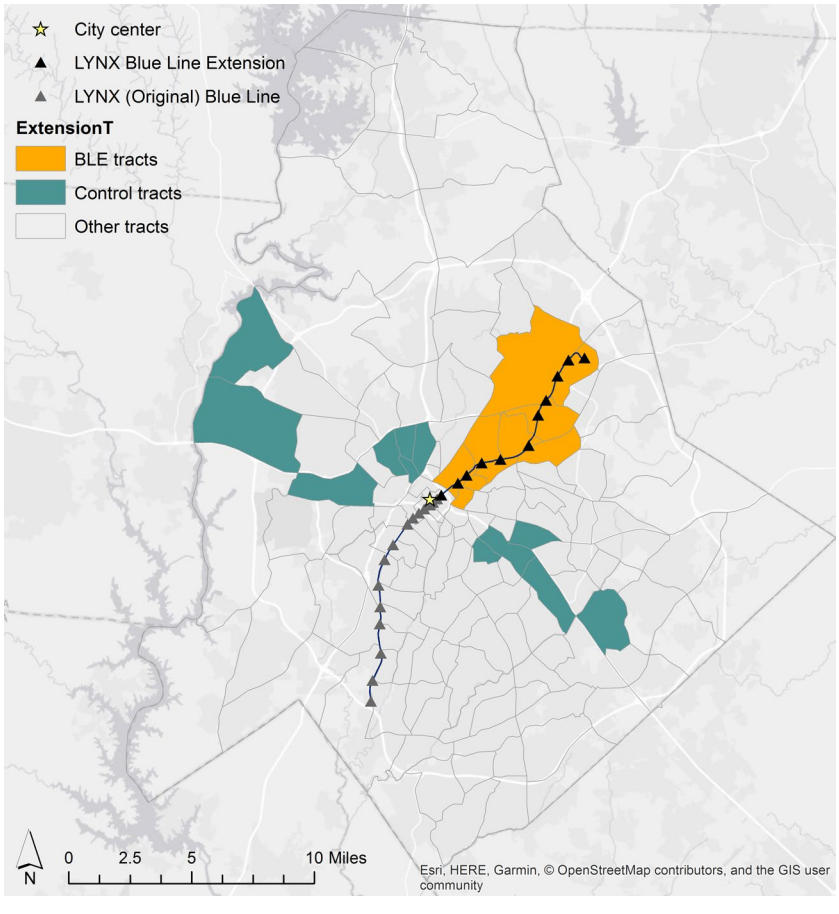

Figure 2. Transit and control neighborhoods.

Table 1. Transit versus Control Neighborhood Characteristics in 2006

	Transit	Control	All other
Tract-MSA median household income ratio (%)	68.91 (26.04)	70.32 (27.68)	124.12 (54.44)
Median home value ($1,000)	83.81 (28.14)	85.83 (27.36)	161.64 (82.32)
Owner-occupied housing units (%)	38.60 (18.73)	45.77 (22.47)	59.91 (22.42)
Multifamily housing units (%)	25.49 (25.07)	20.43 (20.64)	23.98 (19.84)
Minor population (%)	76.49 (24.38)	65.88 (30.47)	33.93 (27.41)
Poverty (%)	21.58 (10.82)	16.79 (11.37)	9.61 (9.96)
Median applicant income ($1,000)	48.08 (10.52)	48.83 (10.52)	76.53 (31.70)
White applicants (%)	51.42 (19.01)	47.57 (30.40)	68.29 (20.71)
Black applicants (%)	33.40 (17.62)	40.19 (32.85)	16.92 (20.26)
Distance to CBD (miles)	2.91 (1.83)	3.48 (2.49)	5.86 (3.82)
N	12	12	112

fewer minorities, a greater share of white applicants, higher applicant incomes, and higher shares of owner-occupied housing. These differences underscore the importance of our treatment and control comparison approach. In the absence of the light rail investment, we would not expect the remaining census tracts in the county to exhibit similar trends to the treatment neighborhoods (on average), making the selected controls a more comparable group of neighborhoods to the treatment group.

To determine which relevant neighborhood amenities to include in the model, we performed a text analysis on the Zillow ad descriptions. We began by geocoding the Zillow data that we collected from 2016 to 2018 to assign a neighborhood to each observation. The world geocoding service from ArcGIS 10.6 was used to geocode the addresses. We then analyzed the most frequently occurring words for each neighborhood, removing words from the database that were generic descriptions properties (such as "bedroom," "kitchen," "bathrooms") as well as common "stop words" (such as "the," "and"). We combined all mentions of light rail to one word "lightrail." All text analysis was performed using the package "TidyText" in R (Silge and Robinson 2016).

Another amenity that may also play a role is school quality. However, this becomes difficult to control for in Charlotte as school district boundaries are changed frequently and there is a rather large presence of charter and magnet schools. To account for school district quality and other unobservables, we include neighborhood (tract) and year fixed effects in all estimated models.

Results

Exploratory text analysis

We collected 1,404 records from Zillow of properties sold in neighborhoods falling within a half mile of a transit station between 2016 and 2018. The spatial distribution of these property records is mapped in Fig. 3a. To give a sense of the differences in property values along this corridor, we created a simple spatial interpolation of the sales price associated with each record in Fig. 3b. Together, the maps from Fig. 3 illustrate that the highest priced properties and neighborhoods are located closest to the city center including: Belmont, Villa Heights, Noda, and Shamrock.

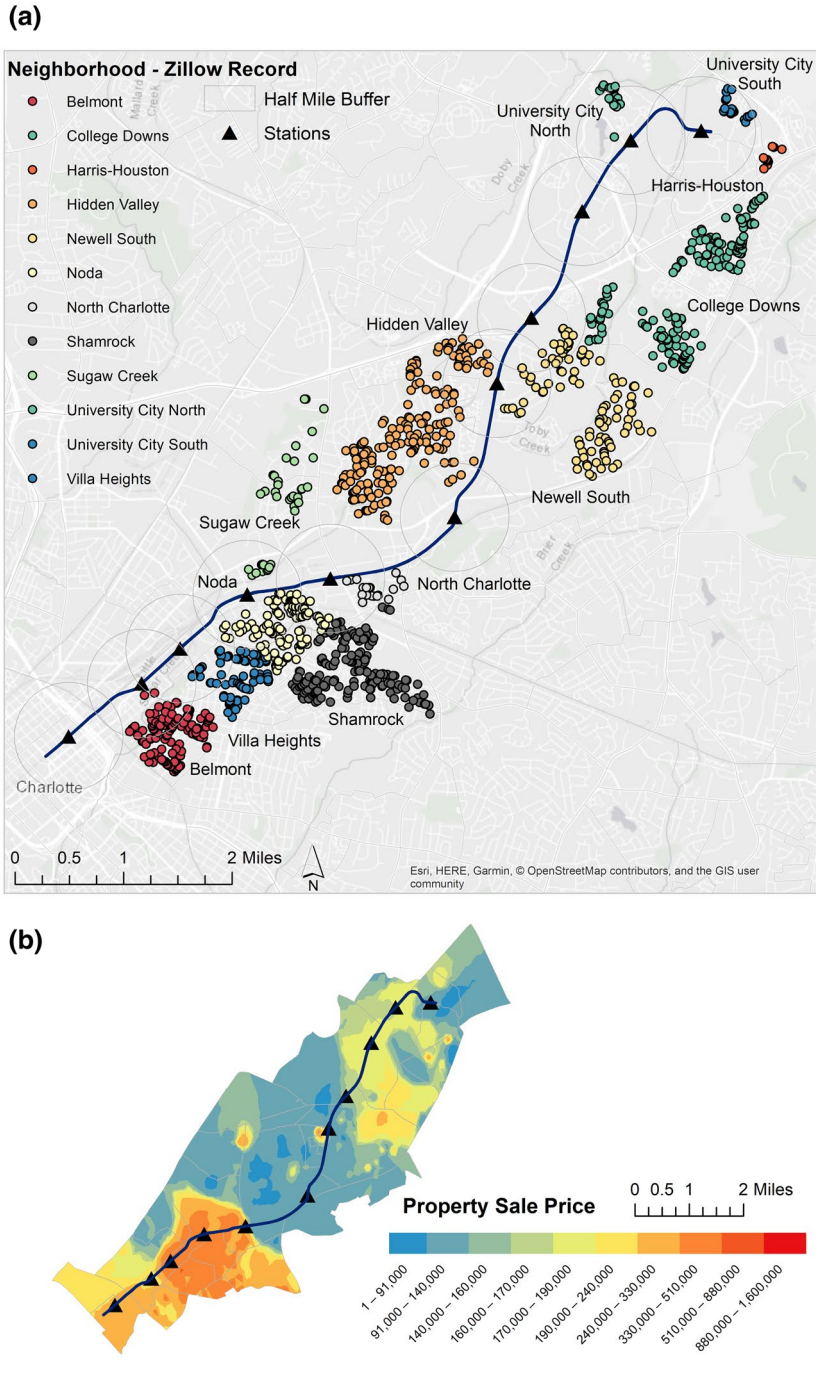

Figure 3. (a) Spatial distribution of Zillow records by neighborhood; (b) Interpolated map of property sale values in the BLE corridor.

Property values then dip in the center of the corridor and rise again slightly at the northern end of the line close to the terminus at the campus of the University of North Carolina at Charlotte.

Our first examination of the text from these property records consisted of a simple search and quantification by neighborhood of the term "light rail." Of all the records, 23% of property advertisements mentioned the light rail and this varied rather significantly by neighborhood. The light rail was mentioned in 58% of records in the "Noda" neighborhood, short for North Davidson, also referred to locally as the "Arts District." Between 2000 and 2010, Noda underwent the most significant transformation in terms of socioeconomic ascent in the city (Delmelle et al. 2013). As shown in the maps in Fig. 3 (just east of the fourth station, north of the center city), it contains the highest property values in the corridor. The next highest neighborhoods advertising the light rail are those flanked on either side of Noda: North Charlotte, a small collection of properties just north of Noda and Villa Heights, the neighborhood immediately south with similarly high property values. These three neighborhoods are approximately 2–3 miles from the center city.

We next graphed the 10 most frequently used words by neighborhood in Fig. 4 to understand what other amenities or characteristics are used to attract buyers to these neighborhoods, and to assess the relative importance of light rail, compared to other features. We opted to leave the name of the neighborhood in the list of words as very attractive neighborhoods with a strong identity appear in property advertisements much more frequently than less prominent neighborhoods. Light rail appears on the list for Hidden Valley, tied as the seventh most commonly occurring word. Other more frequently used words refer to the rather modest attributes of this single-family neighborhood comprised of ranch homes, located in the center of the corridor. Light rail is the fourth most common attribute in Noda, just behind "granite," and above "restaurants," illustrating its prominence within a list of higher end amenities. It also appears on the list for North Charlotte, a small collection of homes just around the new transit station; Sugaw Creek, where proximity to Noda and its amenities registers as the most commonly occurring descriptor, and Villa Heights, where proximity to light rail is prominent, just higher than access to Noda, walkability, and uptown. Other characteristics in Villa Heights are indicative of the transformation taking place in that neighborhood: "remodeled" and "construction." The neighborhoods furthest from the center city and closest to the university make little-to-no mention of the light rail, instead advertising its proximity to the university as well as restaurants and shopping. Thus, this text analysis suggests that light rail is an important amenity in locations that are already amenity rich: close to Charlotte, walkable, and with a high concentration of restaurants and in those with the most expensive housing. We next incorporate some of these indicators into our models of homebuyers in this corridor to isolate the relative importance of proximity to the light rail in shaping demographic shifts.

Mortgage lending trends

We begin by examining trends in income and racial composition of home loan applicants in the BLE and control neighborhoods. We compare these to overall trends in Charlotte, before and after the announcement of the BLE. Figs. 5 and 6 show the mean applicant (nominal) income (in $1,000) and the share of Black or African American applicants between 2006 and 2017. Generally, both the treatment and control neighborhoods tend to follow city wide trends. However, there are a few noteworthy observations. While the BLE tracts closely follow the control tracts in terms of applicant income up to the announcement year, following the announcement

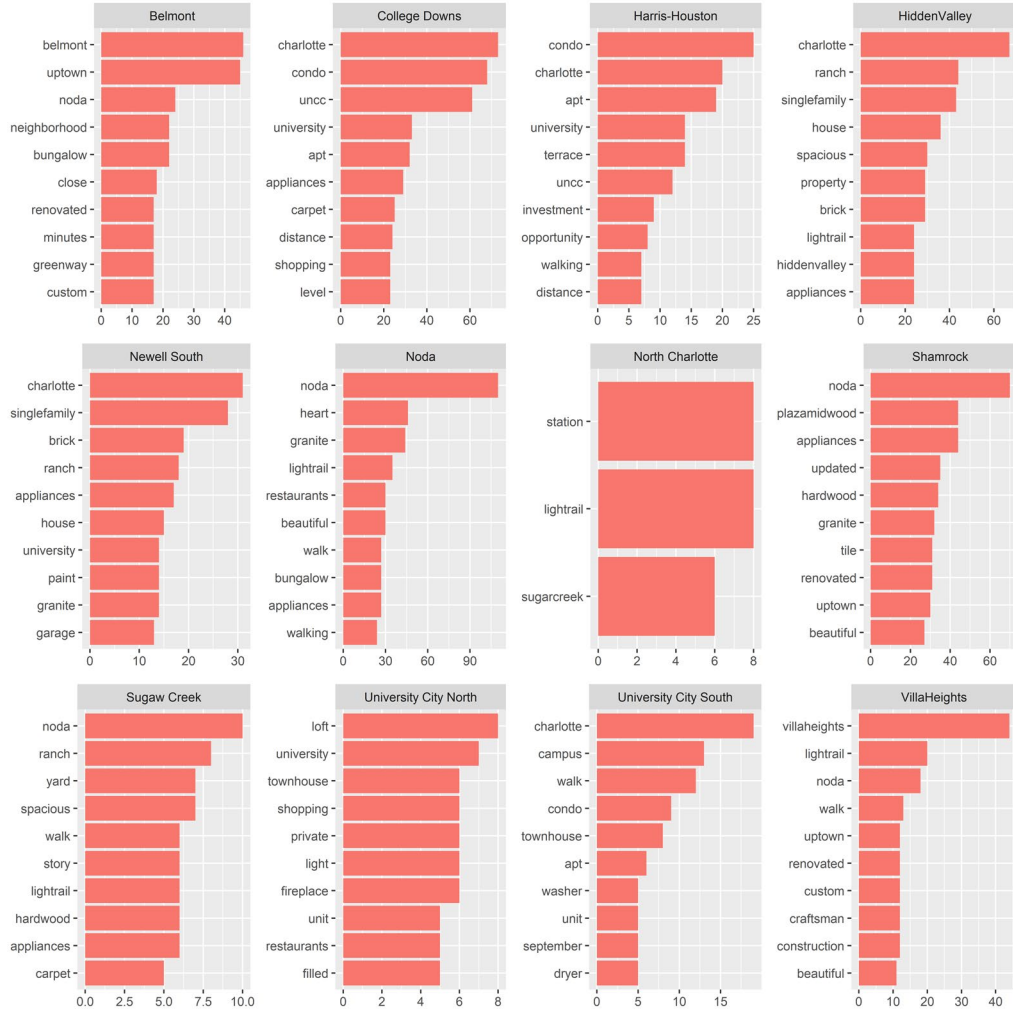

Figure 4. Ten most frequently used words in advertisements by neighborhood.

of the BLE (lagging by about a year), incomes start increasing at a greater rate in the BLE tracts compared to the control tracts.

It is worth noting that the tracts along the BLE as well as the control tracts are comprised of a large share of minority rich neighborhoods. Therefore, it is not surprising to see a larger share of Black or African American applicants in these neighborhoods compared to the city average. As with mean applicant income, BLE and control neighborhoods follow a similar trend preannouncement, however, about a year after the announcement, the share of Black applicants in the BLE neighborhoods starts to decline at a more rapid rate than in the control tracts and compared to wider city trends.

There are, however, differences along the line. Fig. 7 shows differences in the distribution of some selected indicators between 2006 and 2017. Generally, neighborhoods closer to the city center have higher levels of demand (measured by loan originations per housing unit) and applicants tend to be of relatively higher income. They also have a higher share of White applicants.

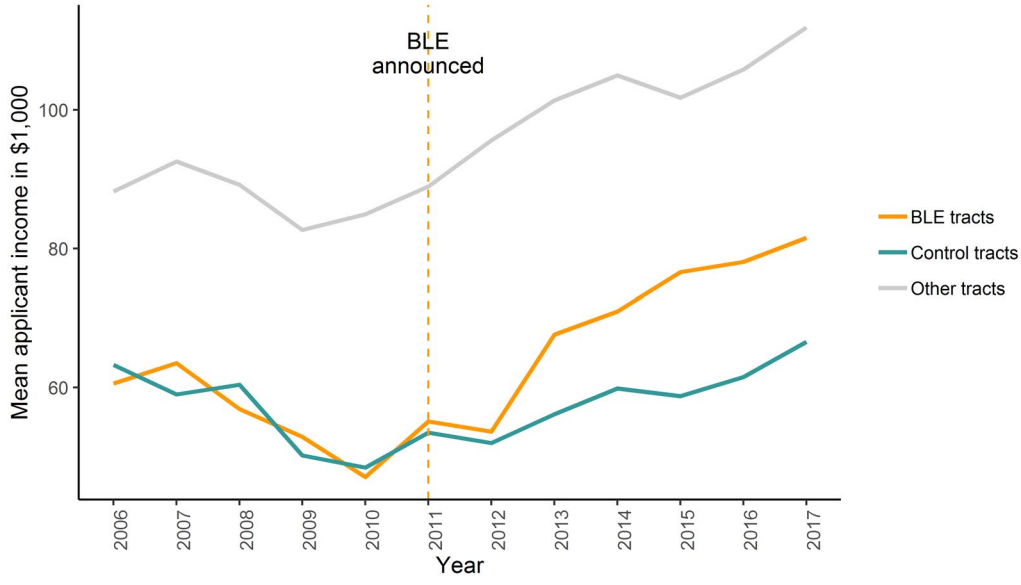

Figure 5. Mean applicant income in $1,000.

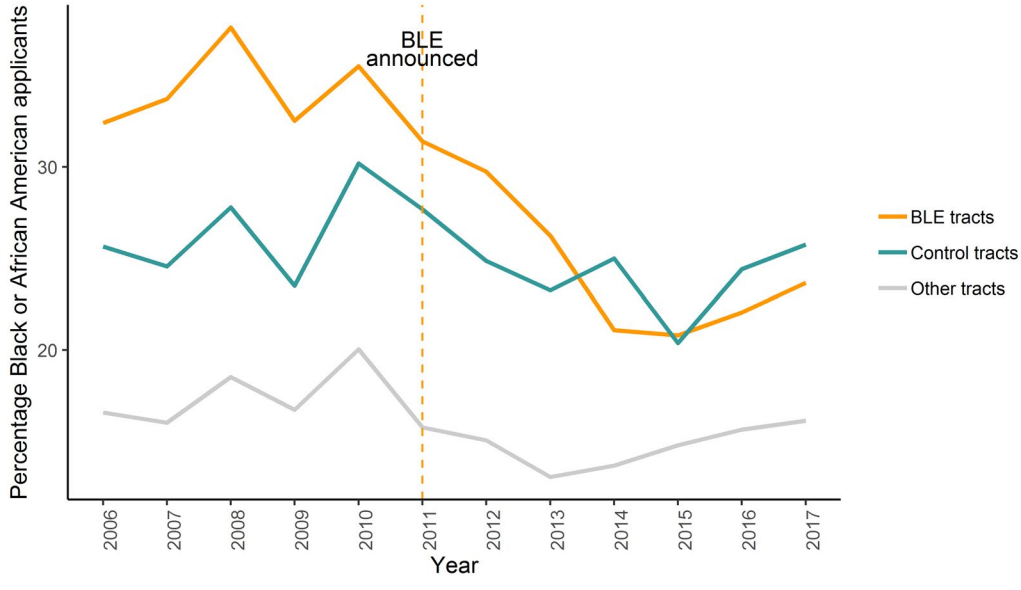

Figure 6. Share of Black or African American applicants.

In 2006, we see that this is especially the case in the Noda and North Charlotte area (near the 25th Street, 36th Street, and Sugar Creek stations). This pattern is enhanced and appears to have spread to adjacent neighborhoods in 2017, mirroring the pattern of sale prices shown in Fig. 3b. In 2017, we also see some increases in applicant income and share of Whites in the University area while areas in between these two end points continues to experience relatively less demand, mainly from relatively lower income applicants.

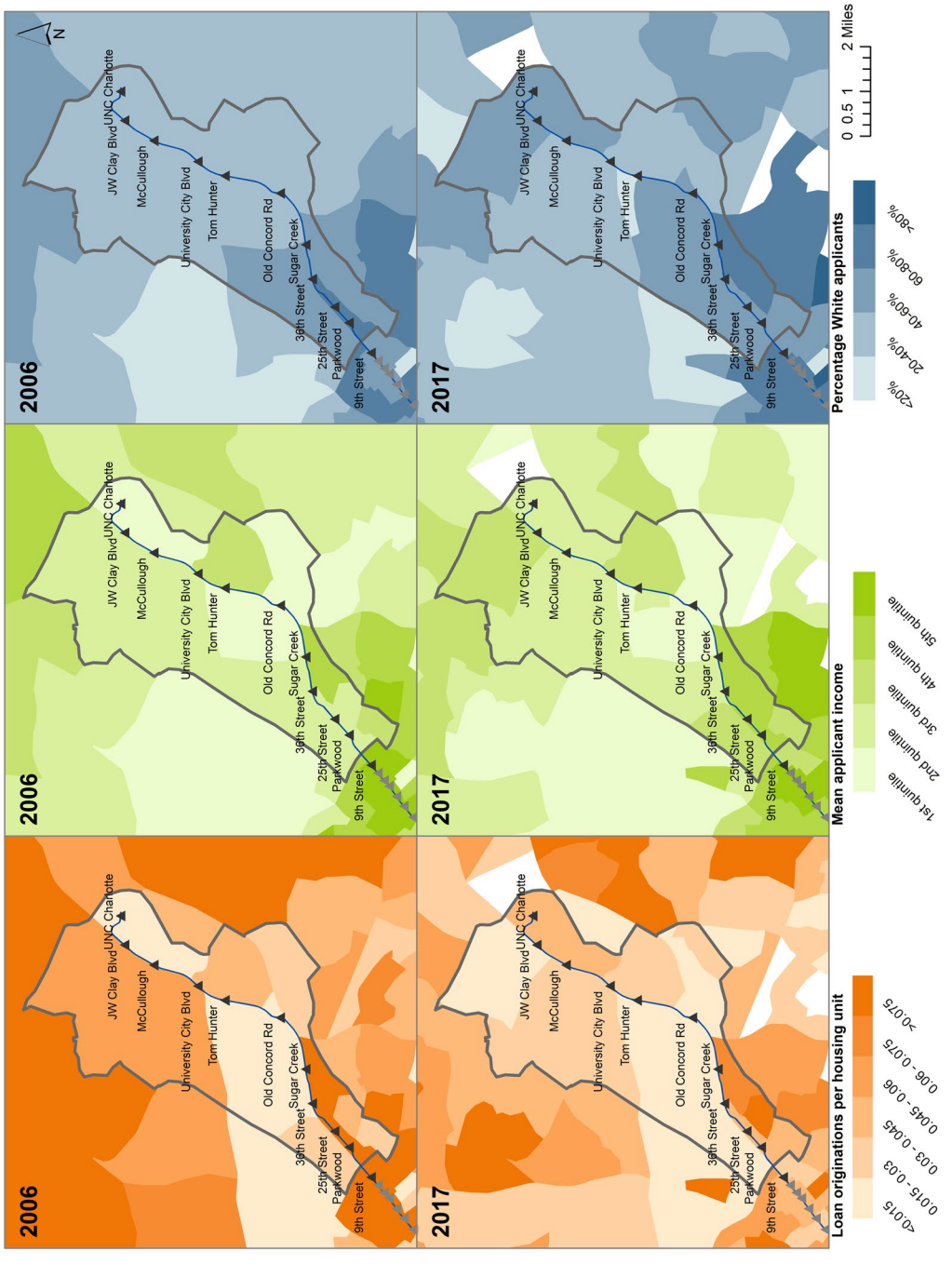

Figure 7. Distribution of selected indicators along the line in 2006 and 2017.

Table 2. Odds Ratios for LMI versus MIUP Applicants

	(1) LMI applicant	(2) MIUP applicant
Postannouncement	0.2689***	3.7186***
BLE neighborhood	0.3398***	2.9432***
Postannouncement × BLE	0.8873	1.1271
Distance to CBD	1.8730***	0.5339***
Distance to CBD^2	0.9421***	1.0614***
Tract-MSA income ratio	0.9964	1.0036
Owner-occupied units (%)	0.9925***	1.0075***
Median housing value	0.9999	1.0000
Minority population (%)	1.0059*	0.9942*
Poverty (%)	0.9963	1.0037
Walkability	1.0022	0.9978
Local restaurants	1.0079	0.9922
Breweries	1.0407	0.9609
Art galleries	1.0466	0.9555
Year and neighborhood FEs	Yes	Yes
N	18,602	18,602
Log-likelihood	−11,546	−11,546
LR χ^2	2,449***	2,229***
Pseudo R^2	0.096	0.096

***Statistical significance at the 1% level.
**Statistical significance at the 5% level.
*Statistical significance at the 10% level.

Next, we turn to the results from estimating the model outlined in Equation (1). Table 2 shows the estimated odds ratios of the independent variables with the dependent variable being (1) whether an applicant is considered low-moderate income (LMI) and (2) middle-upper income (MIUP). To define LMI and MIUP we follow the definition set out in the Community Reinvestment Act regulations where low- and moderate-income households are those with less than 80% of the median family income in the MSA. Similarly, MIUP applicants are those with incomes greater than 80% of the MSA median family income. As expected from Fig. 5, applicants tend to be of higher income postannouncement and in BLE neighborhoods (on average). However, the model is not able to pick up a statistically significant difference in the postannouncement period in the BLE neighborhoods. As for the other variables of interest, distance to the city center and its squared term shows that higher income applicants are more likely to apply for a loan in (both BLE and control) neighborhoods closer to the city center as well as further out in the suburbs. This confirms the patterns shown in Fig. 7 with higher applicant incomes in the neighborhoods near the urban core and at the end of the line in the University area and lower incomes in between. Other variables that are of significance are home ownership rates and minority population, with higher income applicants more likely to apply in neighborhoods with higher rates of home ownership and lower share of minority residents. The amenity variables including walkability, number of local restaurants, breweries, and art galleries are not significant in predicting applicant income level.

Table 3. Odds Ratios by Race

	(1) White applicant	(2) Black applicant
Postannouncement	1.0351	0.7421**
BLE neighborhood	0.4827***	1.9851***
Postannouncement × BLE	1.2278***	0.8219***
Distance to CBD	0.8469	0.7739*
Distance to CBD^2	1.0264***	1.0009
Tract-MSA income ratio	1.0031	1.0069***
Owner-occupied units (%)	1.0023	0.9947**
Median housing value	0.9999	1.0000
Minority population (%)	0.9990	1.0035
Poverty (%)	1.0087*	1.0029
Walkability	1.0250***	0.9633***
Local restaurants	0.9863	1.0113
Breweries	1.0030	0.7821**
Art galleries	0.9465	1.0111
Year and neighborhood FEs	Yes	Yes
N	20,996	20,996
Log-likelihood	−13,690	−10,969
LR χ^2	1,624***	22,279***
Pseudo R^2	0.056	0.094

***Statistical significance at the 1% level.
**Statistical significance at the 5% level.
*Statistical significance at the 10% level.

As for the race of applicants, the results in Table 3 show that White applicants are not more likely to apply for home mortgages postannouncement, but Black applicants are less likely to apply. This finding can be connected to those by Hammel and Nilsson (2019) who found a lower number of Black applicants applying for home purchase loans in the period after the financial crisis in 2008. They suggest a self-selection of exceptionally qualified Black applicants applying for home purchase loans in the more restrictive lending environment that followed the financial crisis. The results in Table 3 also suggest that Black applicants were generally more likely to apply for loans in BLE neighborhoods before the announcement of the light rail, but less likely postannouncement (compared to the control neighborhoods). Whites, on the other hand, were more likely to apply for loans in BLE areas after the light rail was announced.

One explanation behind the lack of significance for income, but significance for race, two variables that are often highly correlated, could be that new White residents moving into center city neighborhoods close to the transit line are younger professionals at the start of their careers. Given that applicant incomes reported in HMDA are the combined incomes of an applicant and potential coapplicant, younger, single applicants may not register as having a higher than MSA average income. This explanation fits with neighborhood-level analyses that have emphasized increases in younger, childless, higher educated residents in new transit neighborhoods (Nilsson and Delmelle 2018). The HMDA data unfortunately do not include information on educational attainment.

As for the other variables of interest, White applicants are significant more likely to apply for houses in more distant suburbs while Black applicants are less likely to apply for homes further away from the city center. Homes in more walkable neighborhoods tend to be more attractive to White applicants than Black applicants. The spatial distribution of breweries in Charlotte is very concentrated with two main clusters: in the city's Southend district (which is not part of our analysis) and Noda (Nilsson and Reid 2019). Neighborhoods with a great number of breweries, which in this case would be the Noda neighborhood along the BLE, are less likely to see Black applicants applying for home purchase loans. On average, Noda tends to attract White and MIUP applicants. The fixed-effect odds ratio for Noda is 1.82 for White applicants and 0.32 for Black applicants (both statistically significant at the 1% significance level). Similarly, the estimated odds ratio for Noda in the applicant income estimations suggest that MIUP applicants are twice as likely to apply for home purchase loans in Noda than low-moderate income applicants (also significant at the 1% level).

Since we do not have information on those moving out, it is plausible that the gains in new White homebuyers are offset by an increase in Whites moving out, leading to a stable racial composition of neighborhoods. To get a better sense of how the neighborhood's overall racial composition may have changed following the announcement, we estimate a neighborhood-level model with percent minority population as the dependent variable through ordinary least squares (OLS) given the nature of the dependent variable. The model includes the other neighborhood amenity variables included in the original model specification as well as neighborhood and year fixed effects to control for unobservables. The results are presented in Table 4.

Overall, both BLE and control neighborhoods had higher shares of minority population in the postannouncement period. As expected from the descriptive statistics of the BLE and control neighborhoods in 2006 (Table 1), the BLE neighborhoods had a relatively higher share of minority residents in the period before the announcement. However, the negative and significant coefficient of the interaction term between the postannouncement and BLE neighborhood

Table 4. Neighborhood-Level Model of Racial Composition

	Minority population (%)
Postannouncement	11.0044***
BLE neighborhood	10.8729***
Postannouncement × BLE	−5.5960***
Distance to CBD	−7.6537***
Distance to CBD^2	0.3451*
Walkability	0.2308**
Local restaurants	0.7392**
Breweries	−11.6394***
Art galleries	2.8206**
Year and neighborhood FEs	Yes
N	264
F-statistic	69.75***
Adjusted R^2	0.91

***Statistical significance at the 1% level.
**Statistical significance at the 5% level.
*Statistical significance at the 10% level.

dummy suggest that the share of minority residents decreased in the BLE neighborhoods postannouncement. This provides some evidence that the relatively larger increase in White applicants and reduction in Black applicants in the BLE neighborhoods after the announcement (as indicated by the results in Table 3 and Fig. 6) may have resulted in a shift in the overall racial composition of transit neighborhoods.

With regards to the other neighborhood amenities, walkable neighborhoods closer to the city center tend to have a relatively larger share of minority residents as well as the most distant suburban neighborhoods (as indicated by the coefficient of the squared term of the distance to the CBD). Neighborhoods with many local restaurants and art galleries also tend to be more diverse while neighborhoods with a high concentration of breweries tend to be less diverse. However, as noted regarding the results in Tables 2 and 3, this may be reflecting the particular case of NoDa which in this model has a significant fixed effects coefficient of −41.02 (the greatest in magnitude of all estimated fixed effects) suggesting a much smaller share of minority residents in this neighborhood across the study period.

Conclusions

Popular discourse on the development of new rail transit lines centers on rail investment's potential for economic revitalization, gentrification, and possible displacement effects. Thus, these investments tend to be contentious as cities try to balance economic development goals with social equity and affordable housing concerns (Rayle 2015). The literature to date on neighborhood outcomes following new transit investments has been far from unanimous, pointing to highly context-dependent outcomes both between and within MSAs. It has also overwhelmingly featured aggregate-level analyses at course temporal intervals. In this analysis, we examined individual-level actions at a fine temporal scale to get a closer understanding of changes in the demographic and income profile of those moving into neighborhoods along a new transit corridor. Our case study of a new transit line in Charlotte, North Carolina used data from the HMDA to model the probability that a loan applicant was White, Black, low-moderate, or MIUP in both the new transit neighborhoods and a set of comparable control neighborhoods throughout the city. We found that the announcement of the new rail line in transit neighborhoods had no impact on the income profile of loan applicants. However, we did find a significant shift in the racial profile of applicants: following the announcement, White applicants were significantly more likely to apply for home loans in transit neighborhoods and Blacks were significantly less likely to. Prior to the announcement of the new transit line, Blacks were more likely to apply for loans in the transit corridor. This appear to have resulted in a change in the racial composition of these neighborhoods as we find a significant reduction in the share of minority residents postannouncement. This racial shift agrees with some other neighborhood-level analyses of transit impact that have reporting on an increasing share of White residents (Pollack, Bluestone, and Billingham 2010; Hess 2020).

While we do not find a significant increase in the likelihood of higher income earners applying for homes in transit neighborhoods postannouncement, this group was already more likely to apply for loans in these areas before the announcement of the new transit line. Furthermore, without being able to control for educational attainment, applicants, especially those near the urban core neighborhoods, are generally younger and may be in the beginning stages of their careers or single households. A sole entry level, even professional job may register as low or moderate household income, but this profile is often thought of as a higher socioeconomic status. Therefore, one limitation of this analysis is the lack of data on educational attainment of individuals.

The combination of an exploratory text analysis of property advertisements in transit-adjacent neighborhoods along with the statistical analysis of loan applications helped paint a more complete portrait of the differential impacts that transit plays in shaping neighborhood outcomes. The light rail was featured most prominently in property ads from the most expensive and most established neighborhood along the corridor, Noda, the city's arts district. Light rail was advertised alongside other high-end amenities such as "granite," and adds to an already amenity-rich neighborhood profile, accompanying words such as "walkable" and "restaurants." It competed in importance in adjacent neighborhoods with proximity to Noda itself. Thus, the importance Noda neighborhood in driving the results found for the light rail neighborhoods should not be understated. Given our significant racial shifts, it is plausible that the announcement of the extension of the light rail, following the highly successful implementation of the original line in transforming the southern corridor, signaled to White homebuyers that the northern corridor was a stable place to invest in. One interesting avenue of future research would be to directly incorporate how often light rail was mentioned in the property advertisements as an explanatory variable in our models. This would require a property advertisement database that covered the duration of our longitudinal model which we do not have at this time.

In terms of other neighborhood amenities advertised in the property advertisements, only walkability registered as significant in attracting White applicants. We also found that neighborhoods with a larger share of breweries, namely Noda in this case, had significantly lower shares of Black applicants. Proximity to the city center was significant in attracting middle- and upper income earners in both the transit and control neighborhoods, fitting in with other studies on the reversal in sorting trends across U.S. cities (Couture and Handbury 2015).

While our analysis highlighted important shifts in homebuyers along a new transit corridor, our study is not without limitations. First, we only examined homeowners and did not look at characteristics of renters. Owner-occupied housing units constitute about 60% of the overall housing market in Charlotte, leaving a significant portion renter occupied. The rental market is likely more responsive to changes in neighborhood characteristics and property values than the owner-occupied market, partly due to the relative ease of moving as a renter. Therefore, results may be more pronounced if we were to include renters, especially in the case of low-moderate income households that are less likely to be homeowners. Unfortunately, there is no comprehensive and easily accessible data source for rental listings, making such an analysis difficult, but a fruitful area of future research. We are also unable to determine if new homebuyers are displacing previous renters along this corridor. Second, we limit our analysis to 1–4 unit buildings mainly due to changes in how HMDA has changed coding of housing types across time, making comparisons across time for multiunit condominiums difficult. Third, our quantitative analysis does not capture the experience of residents living in this corridor and so we are currently performing a complementary qualitative analysis with residents to gain their perspectives on changes. Fourth, we are only able to observe homebuyers moving into a neighborhood and not those moving out. Therefore, we are not able to account for the net change in neighborhood composition. Although, we do estimate a neighborhood level model and find a significant decrease in the share of minority residents after the announcement of the light rail, consistent with our findings at the applicant level. Finally, how generalizable this case study is to the experience with other cities has yet to be determined—is a previously gentrified neighborhood key in explaining whether a transit line will lead to racial changes along transit corridors in other cities? Is transit always marketed as a higher end, luxury amenity in wealthier neighborhoods? These are questions worth investigating in cities. Given the national scope of the HMDA data and Zillow for

property listings, we can compare the case of Charlotte to others that have recently implemented a new transit line. Despite these limitations, this analysis has illustrated how textual information present in property advertisements can inform and complement more traditional statistical analyses of neighborhood dynamics. This workflow has the potential to advance our understanding of neighborhood dynamics in other contexts as well.

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