QUANTIFYING LIGHT RAIL'S EFFECT ON INTRAURBAN DISTRIBUTION OF ECONOMIC ACTIVITY AND COMMUTING PATTERNS

by

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ABSTRACT

MARYAM KHABAZI. Quantifying light rail's effect on intraurban distribution of economic activity and commuting patterns (Under the direction of DR. ISABELLE NILSSON)

This dissertation consists of two consecutive parts. The first part examines the impact of light rail transit (LRT) investment on the type of jobs (i.e., industrial and wage composition) in neighborhoods adjacent to rail transit stations using Charlotte, NC as a case study. Applying a quasi-experimental approach, this research aims to address to what extent LRT affects the industrial and wage composition of jobs and workers in neighborhoods adjacent to the LRT stations. I use data from the LEHD Origin–Destination Employment Statistics (LODES) between 2002 and 2014. The results show no significant increase on employment in adjacent neighborhoods after the introduction of the LRT. However, the industrial makeup of the area has been changed. Additionally, the LRT appears to connect higher-wage neighborhoods to areas with significant shares of higher-wage jobs. However, low- and medium-wage workers have not seen much change. The second part examines the impact of LRT on commuting patterns in adjacent neighborhoods. The results show a reduction in commuting distance experienced by higher-wage workers, while it is increased for lower-wage workers after the opening of the city's first LRT line. These results are expected as the LRT connects higher-wage neighborhoods to the areas with significant shares of higher-wage jobs. Therefore, low- and medium-wage workers in the LRT adjacent neighborhoods have not seen a significant improvement in the spatial separation between their work place and place of residence after the opening of the LRT, which may conflict with goals of increasing accessibility for the most transit dependent population.

DEDICATION

To Mina Tafazoli, and Hamid Khabazi, my beloved mother and father for their endless support, dedication, and love, and their limitless kindness and selflessness during my entire life.

To my second but genuine beloved mother and father, Mitra Noori and Saeid Razmyar, for their unlimited understanding and authenticity. I could not ask for any better mother- and father-in-laws in my life.

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To my soulmate, my dream partner, MY TRUE LOVE, Roozbeh Razmyar, without whom I couldn't have the best last year of my PhD. Like Carl Sagan in Cosmos well said, "In the vastness of space and immensity of time, it is my joy to spend a planet and an epoch with" … "Roozbeh"

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LIST OF ABBREVIATIONS

LEHD	Longitudinal Employer-Household Dynamics
LODES	LEHD Origin-Destination Employment Statistics
LRT	Light Rail Transit
OD	Origin-Destination
RAC	Residence Area Characteristics, jobs are totaled by home Census Block
WAC	Workplace Area Characteristics, jobs are totaled by work Census Block

CHAPTER 1: INTRODUCTION

Public transit provides means to connect residents with employment, social services, and other opportunities (Pendall et al. 2015). However, transportation improvements, such as investments in rail transit, change how economic agents interact with and across space. It affects households, workplace, and firms location decisions (Severen 2018). Such changes may affect the effectiveness of transportation investments as a way of connecting people and jobs either positively or negatively, by creating a better or worse match between jobs in transit-adjacent neighborhoods and the skills of those who live in these neighborhoods. While there is a relatively large literature on rail transit and residential sorting and subsequent changes in socioeconomic and demographic characteristics of neighborhoods (Cervero 2007, Kahn 2007, Pollack et al. 2010, McKinnish et al. 2010, McKenzie 2015, Deka 2016, Nilsson and Delmelle 2018), little attention has been paid to changes in the types of jobs (i.e., industrial and wage composition) in neighborhoods adjacent to rail transit stations and how that consequently affects the commuting patterns in those neighborhoods. Thus, the first part of this research fills this gap by studying changes in the industrial and wage composition of neighborhoods adjacent to light rail transit stations as well as characteristics of workers living in these neighborhoods. As an expected result of these changes, in the second part of this research, I focus on the effect of light rail transit investment on commuting patterns in adjacent neighborhoods. LYNX Blue Line light rail in Charlotte, North Carolina, has been used as a case study for this research.

There are several theoretical reasons for why transportation improvements may cause changes in type of firms and workers residing in neighborhoods. Firms seek locations that offer greater opportunities for economic profit. Public infrastructure such as light rail transit can enhance these opportunities by increasing productivity of private inputs and/or by reducing input factor costs (Munnell 1990, Aschauer 2000, Pereira and Andraz 2003, Eloff et al. 2013). As modern economies have become increasingly service oriented and firms have become more depended on the movement of people rather than goods, rail transit can reduce the costs of moving workers and consumers. Rail transit also provides increased regional access to labor markets especially for firms without specialized hiring needs (e.g., retail, personal services and hospitality) (Chatman and Noland 2011, Noland et al. 2014, Credit 2017). Moreover, the increased pedestrian traffic generated by rail transit riders may attract retail and service firms seeking locations (Schuetz 2015). Hence, rail transit investments are likely to spur economic activity around stations. The accessibility offered by rail transit is likely to increase the demand for these locations by firms, which in turn puts an upward pressure on land and property values, which has been documented in several studies (Billings 2011, Bowes and Ihlanfeldt 2001, Debrezion et al. 2007). The types of firms that are willing to pay these higher premiums are going to be those that value the accessibility that rail transit offers. Therefore, depending on the current industrial composition of the neighborhoods adjacent to the rail transit stations, rail transit investments may cause changes to its industrial composition and the type of jobs accessible by this new rail transit infrastructure.

Similarly, rail transit investments may alter who lives in neighborhoods adjacent to the stations. If residential property values and rents increase due to public investments such as light rail, existing lower-wage workers may end up having to leave due to not being able to afford, or willing to pay for, this amenity (Pollack et al. 2010, TCRP 2004, Tiebout 1956, Zuk et al. 2018). Furthermore, if considering market potential, rail transit and associated transit-oriented development may be implemented in areas where socioeconomic changes (e.g., gentrification) are already occurring (Nilsson and Delmelle 2018). In fact, it has been shown that new housing built near rail stops often appeals to single professionals and childless couples (TCRP 2004). Hence, we may find that rail transit is implemented in neighborhoods which already have a large share of white-collar workers and jobs in order to maximize ridership (and return on investment from transit-oriented development).

In summary, spur of economic activity and relocation of firms may alter the industrial composition and consequently the types of jobs in the neighborhoods adjacent to the rail transit stations. As documented in the existing literature, rail transit investments can also affect residential sorting and hence the socioeconomic characteristics in the neighborhoods adjacent to rail transit stations. Hence, these two simultaneous modifications of residential and industrial composition (in other words land use change) around light rail stations may affect job accessibility of different residents with different transportation demands.

Applying a quasi-experimental approach, the first part of this research investigates the link between investments in light rail transit and changes in industrial and wage composition in adjacent neighborhoods. Therefore, the first research question of this dissertation is: to what extent rail transit affects the industrial and wage composition of jobs and workers in neighborhoods adjacent to fixed rail stations? For this analysis, I use data from the Longitudinal Employer-Household Dynamics (LEHD) Origin–Destination Employment Statistics (LODES) for the time period of 2002 to 2014.

The results show that the affected, or treated, neighborhoods (proxied by census blocks) have a pre-existing advantage in terms of level of employment and number of residents even before the presence of the light rail. Particularly, the treatment blocks have a higher share of higher-earning jobs and higher-level jobs (e.g., in sectors such as information, finance, insurance, professional services, and headquarters) both among residents that live there and the workers that work there. These results show that the placement of the light rail was mostly to connect higher-earning workers or residents to higher-level jobs, which is contradictory to one of the goals associated with public transit investments which is to increase accessibility to the job opportunities for transit dependent individuals and decrease the spatial mismatch. However, the connectivity to higher-skill, higher-earning jobs that the LRT offers may have more economic benefits for cities by increasing property values and property tax revenue.

As noted earlier, in the second part of this research, I focus on the effect of light rail transit investment on commuting patterns in neighborhoods adjacent to the stations. Major transportation infrastructure is established to address daily trips between work place and place of residence. One of the main goals of public transit investments is to connect people with jobs and increase employment rates by reducing spatial separation between workplaces and residents. However, improved accessibility through rail transit investments affects economic agents' location decisions. Firms dependent on foot traffic value higher accessibility and would be attracted to neighborhoods where accessibility has been improved. In addition to increased accessibility, Transit-Oriented Development (TOD) encourages mixed-use, high density, and pedestrian friendly development, which further increase demand for areas where rail transit has been implemented. Consequently, neighborhoods where rail transit and TOD has been implemented may experience a boost in economic activity. However, problems arise when this spur of economic activity in affected areas puts upward pressure on property values and rents, making it difficult for low-income residents to afford living in newly revitalized neighborhoods. If this results in lower income residents moving out and higher income earners moving in, cities could expect changes in the commuting patterns of workers, particularly in the neighborhoods adjacent to the rail transit stations post-investment.

The second part of this research investigates such changes by asking the question: which types of workers are commuting to and from neighborhoods affected by rail transit investments and how that has changed over time? Using the same data as the first part of this dissertation, from the Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES), I estimate the association between origin neighborhood characteristics and the share of workers commuting to light rail neighborhoods for work. I also analyze trends in commuting distance faced by different workers groups over time. The results show that commuting distance has increased for lower-wage workers while it has decreased for higher-wage workers. I also find that light rail tends to connect neighborhoods with a large share of high-wage workers to locations with higher shares of higher-wage jobs. Thus, this research lends evidence to suspicions raised in previous literature regarding light rail transit investments being placed in neighborhoods that have or are in the process of undergoing some kind of socioeconomic ascent (Canales et al. 2019, Nilsson and Delmelle 2018).

This research has broader impacts in that it evaluates economic and transportation impacts associated with light rail transit developments at both the neighborhood and city level. This research sheds light on the effectiveness of light rail investments as means for connecting people with jobs, which in turn has impacts on employment outcomes in cities as well as congestion and automotive dependence. It can also assist land-use planning and policy in terms of predicting what types of establishments are more likely to value access to light rail transit stations. Finally, to a certain extent, this research addresses the effectiveness of light rail transit investment as an economic development tool by studying relative employment growth in rail transit versus non-transit neighborhoods. Urban and regional planning and policy decision makers can apply this knowledge about the economic impact of light rail for their future planning and policy decisions. Moreover, they can apply this knowledge for predicting the broader impacts of investments on future light rail lines in other parts of the city.

This research also has intellectual merit in several areas of research that have received recent calls for more work. It contributes to the literature on the impact of light rail transit systems on the spatial distribution of employment within city and its metropolitan area that is a concern for urban economics and geography (Bollinger and Ihlanfeldt 2003). Employment redistribution has received more interest because of its effect on spatial mismatch, social justice, and urban sprawl (Bollinger and Ihlanfeldt 2003, Sanchez 1999). While businesses tend to move out of the city centers, in general those businesses that need higher education and skills (e.g., managerial and information processing services) remain in central cities, where the lower skilled workers tend to live. While entry-level, low-skilled jobs on the other hand move to the urban fringe and beyond

(Sanchez 1999). Through redistribution of employment within the city and increasing concentration of jobs near rail transit stations, more people can gain access to jobs, which is particularly important for those who do not have access to private transportation. However, the question is that what kinds of jobs are becoming more accessible through rail transit stations? Does light rail transit have any effect on spatial mismatch of jobs and those who are seeking jobs? The goal of this research is to address these questions.

One of the main contributions of this research to the existing literature on public transit and land use change is that I find that higher-income workers tend to choose to live closer to their workplace and hence have shorter commutes. This is in contrast with previous literature such as Alonso (1960) and more in line with more recent trends observed in works by authors such as Ehrenhalt (2012). Alonso (1960) suggests that higher income individuals choose to have a longer commute in return of having better housing options such as more space and quality of housing further out in the suburbs. While this idea still stands for some portion of the working population, which might include households with children, the other portion of the working population that might be younger, childless and high-skilled professionals choose to live closer to their workplace in return of having a shorter commute. This research provide evidence that this population may value time more and choose to live closer to their job location. There are two potential explanation for these findings. First, higher-wage workers value time more because of the higher opportunity costs of commuting and hence they move closer to their job locations. Second, higher income workers are attracted to neighborhoods adjacent to the rail transit stations because of all the amenities associated with transit-oriented development and the accessibility these areas offer. In addition, these changes in commuting behaviors are just for fixed rail transit stations and not for bus stations or highways. Bus stations are not fixed stations and expanding the bus system would not attract private sector invests in an area. Highways, on the hand, because of providing easier and/or faster commutes may encourage longer commuting distances and hence encourage urban sprawl. Thus, findings from research only applies to fixed rail transit investments.

There are however limitations to this research. First, the study uses data aggregated to the census block. Individual level origin-destination data as well as variables such as occupation and travel mode to and from work could help us better understand and more precisely predict commuting patterns and light rail transit ridership. One concern is that when rail transit connects higher-income residents with their workplaces they still may not use the train as their primary mode of transportation and hence return on investment for the city as well as potential environmental and traffic benefits associated with increase public transportation ridership could be lost.

Second, while a representative city, the results are generated through a case study on a rapidly growing city in the United States. While slow growing or stagnant cities are probably less likely to implement fixed rail transit, the results may not be the same for such cities. The economic base of the city may also alter the effects rail transit investments has on the redistribution of economic activity and commuting patterns.

Third, since it has been shown that light rail and heavy rail transit have differing impacts on neighborhood socioeconomic and demographic change (Miner et al. 2019, Nilsson and Delmelle 2018), it is likely that the effects on economic activity and commuting patterns may also differ.

Finally, it would enhance the quality of the results of this study if the LODES data on number of jobs for workers at firms with firm age, and number of jobs for workers at firms with firm size were available for years between 2002 to 2009 (this data is just available for 2009 and over). In that case, we could exactly examine the effect of the light rail investments on industrial composition of the treatment vs. the control group, and understand thoroughly that how the industrial makeup of the area have been changed after the introduction of the light rail by investigating the changes in the age and size of the firms.

CHAPTER 2: LITERATURE REVIEW

2.1. PUBLIC TRANSIT AND FIRM LOCATION

Firms are attracted to locations with greater opportunities for economic profit. Considering transportation costs as a factor of production, minimizing such costs become an important factor in the firm's location decision (Ryan 2005). Therefore, changes in the transportation system have impacts on the distribution of economic activities (Nilsson and Smirnov 2016). As modern economies have become increasingly service oriented and transportation costs faced by firms have become more concerned with the movement of people rather than goods, rail transit can increase accessibility and reduce the costs of moving workers and consumers (Schuetz 2015). However, the majority of literature on firm location and transportation infrastructure has focused on manufacturing activity and/or highways (Chandra and Thompson 2000, De Bok and Sanders 2005, Elgar et al. 2009, Holl 2004, Maoh and Kanaroglou 2009, Nilsson and Smirnov 2016). The urban economics literature suggests that through transit development, costs of ridership decrease, and movement of residents and commuters would be easier from one neighborhood to another. This would influence the market area and potential demand for goods and services. Increasing the number of consumers and buyers would lead to increase in the number of establishments and level of employment (Schuetz 2015).

The accessibility benefits offered by rail transit is likely to increase the demand for these locations by firms and households and that puts upward pressure on land and property values which has been documented extensively in the literature (Debrezion et al. 2007, Mohammad et al. 2013). Increasing land and property taxes stemming from increasing property values in some transit-adjacent neighborhoods is one of the main economic impacts associated with transit-oriented development (TOD). Studies in the literature regarding increase in property values around transit stations include Bowes and Ihlanfeldt (2001), Cervero and Duncan (2002a), Ryan (2005), Gibbons and Machin (2005), Billings (2011), Duncan (2011), Hewitt and Hewitt (2012), and, Ko and Cao (2013). The reason for increase in real estate prices in transit-adjacent neighborhoods is that when a location becomes more attractive (in this case by reducing transportation time and costs), demand increases which starts a bidding process (Alonso 1960) in which prices are pushed up (Debrezion et al. 2007). By increasing the price of land, there will be more land division leading to smaller parcels in cities and finally higher density development. Higher property values closer to rail transit stations implies market capitalization of economic benefits. The types of firms that are willing to pay these higher premiums are going to be those that benefit the most from the accessibility that rail transit offers. Hence, depending on the current industrial composition and land use of transit-adjacent neighborhoods, rail transit investments may cause changes to its industrial composition and the type of jobs accessible by this new transit infrastructure. Many studies to date have examined the impact of light rail development on property values and the results differ widely across different cities, neighborhoods, and types of stations (Debrezion et al. 2007, Holmgren and Merkel 2017). Some studies find a positive impact of rail transit on property values (Nelson 1999, Weinberger 2001, Cervero and Duncan 2002a, Cervero and Duncan 2002b, Fuerst 2008) while some other studies find a negative impact (Bollinger et al. 1998, Cervero and Duncan 2002b, Ryan 2005).

The literature shows mixed results regarding the effect of light rail transit investments and its economic activity outcomes in adjacent neighborhoods. For example, Cao and Ko (2013) find various aspects of the value-added effect of the Hiawatha light rail transit (LRT) system in Minneapolis on commercial and industrial properties by applying hedonic pricing models of firm location choice. They control for multiple structural and location factors and their results suggest that the Hiawatha LRT has increased commercial and industrial property values nearby, and, slightly, revitalized the neighborhoods and stimulated economic development along the corridor. Nelson et al. (2015) estimate the spatial extent of the rent premium by evaluating how office rents is related to the distance to a light rail transit station. "The office rent premium with respect to transit station distance was found here to extend to about 1.85 mi (2.98 km) from all light rail stations in the Dallas metropolitan area, or roughly double the distance Ko and Cao found for combined office and industrial values within 1 mi (1.61 km) of a light rail line. In addition, the rent premium was found to fall rapidly, losing 25% after 0.25 mi (0.40 km), half after about 0.56 mi (0.90 km), and 75% after 0.93 mi (1.50 km)" (Nelson et al. 2015, 113). Ryan (2005) shows the importance of having accessibility to highways and light rail for industrial and office firms. Her results indicate that accessibility to light rail transit is not necessarily important for office or industrial rents, not when compared with freeway access (Ryan 2005). She concludes that the light rail system does not have enough travel cost benefit to cause market to respond in nearby office development, but the light rail should rather pass through areas with high concentration of activities, and that we should not expect that light rail transit will increase and stimulate economic activity (Ryan 2005). Canales et al. (2019) examines whether rail transit stations tend to increase employment opportunities in adjacent neighborhoods. They use a difference-in-difference model to study changes before and after the opening of the first light rail line in Charlotte, NC. They find that the light rail does not have a significant effect on employment opportunities, but they find that the light rail connects to the areas with higher share of higher-income jobs (Canales et al. 2019). My study adds to this analysis, by looking at this problem from a more comprehensive perspective. The effect of the light rail investment is not just on the workers and employment opportunities, but also, it affects the residents in these areas and their decision to move in/out of these neighborhoods. In fact, it is a combination of changes in demand for land and properties and changes in values of land and properties, which affect both workers and residents. Therefore, it is important to examine these changes at the same time to understand this intertwined reciprocal concept of industrial, wage, workers, and residential changes in neighborhoods around the light rail stations. In addition to this analysis, I also study the subsequent effect of these changes on commuting patterns in these areas.

Other studies explore the goals of investments in rail transit in increasing economic activity and encouraging mixed land-use of residential and commercial activity in adjacent neighborhoods (Schuetz 2015). Some scholars have studied the effect of light rail investment on the composition and density of employment. Schuetz (2015) examines the effect of TOD on retail employment near new rail stations across California's four largest metropolitan areas. The result shows no changes on the retail employment after opening of the light rail stations on three of the four MSAs, and it has negative effect on Sacramento MSA (Schuetz 2015). Bollinger and Ihlanfeldt (1997) found in their study that Atlanta's rapid rail transit (MARTA) has had no significant impact on population and employment density. In other words, they found that employment is not higher in areas adjacent to the rail stations than those without access to the rail transit. However, it has changed the composition of employment near the stations in favor of the public sector only in those areas that have more commercial activity. In a later study, they found some different results by adding additional controls to their model. In that study, the results suggest some upsurge in the share of employment at the tract level due to public transit investment (Bollinger and Ihlanfeldt 2003).

In short, studies on rail transit investments effect on employment growth show mixed findings. In some studies, the results show no difference in employment after transit investment. Nevertheless, in smaller scale (neighborhood level) there are changes in employment. Although, Bollinger and Ihlanfeldt (2003) emphasize that these changes in employment is because of redistribution of the economic activities in the region, not because of increasing the employment in the region. They also argue that some public policies support the idea of redistribution of employment within urban areas in favor of depressed neighborhoods within central cities. These policies include neighborhood-based tax incentive programs that provide property tax abatements and job tax credits against the state income tax and also making road improvements within the neighborhood that are effective in the neighborhood's share of regional employment. They suggest that the impact of transportation infrastructure improvements and tax differences within metropolitan areas is larger on the distribution of employment than on the distribution of employment across these areas.

Thus, with the exception of Bollinger and Ihlanfeldt (1997) and Canales et al. (2019), there seems to be a gap in the literature concerning the impact of light rail development on the composition of employment (share of employment in different industry sectors) in affected neighborhoods. Insight into which types of firms value access to rail transit and hence the type of jobs accessible in these neighborhoods are important in order to understand whether rail transit is effective in connecting people with jobs. This of course also depends on the skill level and socioeconomic composition of residents in connected neighborhoods.

2.2. PUBLIC TRANSIT AND COMMUTING PATTERNS

One of the main purposes of public transit investment is to connect residents to employment, social services, and other opportunities. However, transit investments, in particular rail transit, are also often associated with revitalizing declining inner urban areas. Population decentralization is part of most US urban areas since the 1950s (Baum-Snow 2010) and the dispersion of jobs from the US central cities has been a major factor underlying the spatial mismatch hypothesis coined by Kain in his work in 1968 (Sanchez 1999). This hypothesis stated that through suburbanization of employment, the spatial mismatch between inner city African American residents and jobs increased. There is also social isolation of central city residents from middle-class households, institutions, and services (Wilson 2012). Employment suburbanization is more about low-skilled jobs, while a large portion of high-skilled employments remains within central cities. Therefore, the problem is the mismatch of educational and skill levels and requirements of inner city residents with these high-level jobs (Sanchez 1999). Jobs in downtown areas are often managerial and information processing services while suburbs hold more low-skilled jobs (Sanchez 1999). Findings of studies related to mode of transportation and job accessibility show that the lack of accessibility to suburban jobs for inner city residents is because most of the suburban jobs are accessible only by automobile (Shen 1998, Shen 2001, Grengs 2010). Consequently, many scholars change the term of spatial mismatch to "modal mismatch" (Kain 1992, Blumenberg and Manville 2004). Indeed, one goal of public transit investments, particularly rail transit, is to reverse the decentralization trend and support the revitalization of declining inner cities (Nilsson and Delmelle 2018). This is one of the reason that local and federal government have been spending billions of dollars since 1980 to invest on rail transit and particularly on light rail transit (LRT) together with Transit-Oriented Development (TOD). In 2015, local governments in North America spent over $40 billion on light and heavy rail transit construction (Freemark 2015).

Accessibility is the main amenity associated with public transit development. The increased accessibility can reduce spatial mismatch and increase employment participation (Sanchez 1999). In recent decades, several cities in the US have begun to construct light rail systems, which could potentially reduce spatial mismatch and road congestion. Light rail transit mostly connects neighborhoods to downtown area, where there is usually a high concentration of high-skilled jobs in managerial and information processing services. However, with the increasing popularity of TOD, areas close to light rail stations often see an influx of economic activity including opening of retail and other services, which are usually associated with lower-skilled jobs (Schuetz, 2015). Empirical studies on in-movers to the neighborhoods with higher accessibility to light rail transit stations have shown that these residents are of higher socioeconomic status than existing residents are (McKinnish et al., 2010). On the other hand, according to two recent studies by Delmelle and Nilsson (2018) and Rodnyansky (2019), low-income residents do not appear to be more likely to move out of neighborhoods that have recently received rail transit. Regardless, rail transit construction and related changes in economic activity can potentially change commuting patterns in neighborhoods adjacent to the light rail line and modify traffic and congestion.

Commute is a trip that connects homes to jobs, and is essentially affected by the separation of homes and employment locations (Hu et al. 2016). Commuting patterns are bound to several factors including urban structure, available modes of transportation, socioeconomic characteristics of commuters, land use patterns, and location of jobs and housing (O'Kelly and Lee 2005). Commuting cost is one determining factor of urban structure and firms and households' decision-making for their location (Hu and Schneider 2017). Based on urban economic theory, different income groups of people respond differently to the tradeoff between housing size and commuting length (Hu et al. 2016). With the goal of maximizing their utility, given a budget constraint, households have to make tradeoffs between commuting cost, housing cost, and amenities (Hu and Schneider 2017).

Firms' on the other hand make their location choice with the goal of maximizing profits. Changes in urban structure and transportation costs affect profitability of sites and hence firms' location preferences. Nilsson and Smirnov (2016) present evidence that retail firms are attracted to locations in proximity to major transportation infrastructure resulting in increase in the density of establishments around, for example, highway intersections with good accessibility. In general, there is an inherent endogeneity in the relationship between changes in the transportation infrastructure and firms' location choice, where firms are attracted to accessible locations and locations with a lot of employment receive transportation investments. Through increasing decentralization of economic activity in cities, firms' location choices have become less concerned with reducing the cost of transporting inputs and outputs (Ryan 2005) and more concerned with increasing the amenities for their employees and other locational attributes (Wheaton and Torto 1994). One factor they consider is to reduce their employees' commuting cost (Hu and Schneider 2017).

While there are many studies on the effect of light rail transit investment on land value and demographic changes, fewer studies have examined its impact on commuting patterns in and out of these neighborhoods and if there have been any changes to the job-housing balance. By reducing the mismatch between jobs and housing, excess commuting can be reduced. "Excess commuting reflects the surplus of journey-to-work travel caused by the locational mismatch of residence and employment" (O'Kelly and Lee 2005). Most of those studies about commuting patterns have examined whether the length of the commutes have been changed. In terms of the commuting length, studies found that commute trips to the Central Business District (CBD) is usually longer than trips to employment sub-centers (Cervero and Wu 1997). In addition, commute trips to sub-centers are longer than commutes to dispersed workplaces regardless of the commuters' income. This issue indicates that clustered employment centers usually attract people from larger areas that makes the average commuting time longer to these clusters (Hu and Schneider 2017).

A common method of testing the spatial mismatch hypothesis is to measure whether commuting times are longer for minorities than for whites, when controlling for other factors. Researchers use different methods to measure commuting. Some use time of commute to measure commute length. This data is available through Census Transportation Planning Products (CTPP). Others use commute distance and they argue that the distance is a better measure of commuting length because it provides a more consistent metrics to measure. In measuring the commute distance, some researchers use Euclidean distance and some use network distance and apply a zonal centroid-to-centroid approach (Hu et al. 2016). The relationship between time of travel and travel distance is not necessarily monotonic, i.e., that longer distance creates a longer commute time. In fact, it is more likely to observe a nonmonotonic relationship between travel time and travel distance because of diverse socioeconomic attributes of commuters (Niedzielski and Boschmann 2014).

Consideration of mode choice is relevant when examining commuting patterns, since different commuters would use different modes of transportation. Usually modes of transportation include trains (subway, rail) and vehicles (car, carpool, bus, taxi). There are three factors influencing mode choice (Creemers et al. 2012): Characteristics of the trip maker (car availability/ownership, possession of a driver's license, household structure, residential density), type of journey (trip purpose, time of the day that trip is taken), and mode specific characteristics (travel time (in-vehicle time, waiting and walking times), monetary cost (fares, fuel, direct costs), availability and cost of parking, comfort and convenience, safety).Regarding public transportation system factors, one important issue in choosing public transportation is reliability of travel time by that specific public transportation. Other than reliability of travel time, travel cost, in-vehicle travel time, waiting time, access and egress time, transfers, sufficient comfort (air-conditioning, legroom) and availability of seats influence the travelers' mode choice. In addition to public transportation factors, personal traits such as age, gender, income, and car ownership can affect travelers' mode choice (Creemers et al. 2012). Currie et al. (2011) indicate that service level measured as vehicle trips, slower speed, integrated ticketing, and employment density is associated with higher light rail ridership. Based on different studies the most influential factors in light rail ridership are travel cost and in-vehicle time. Thus, keeping the cost low would probably encourage more low- or medium-wage workers to use the light rail and similarly, keeping the time of travel shorter would encourage high-wage workers to use it. However, since the time of travel for light rail is fixed, it is more probable that the only users of light rail would be low- and medium-wage workers. In general, men tend to use light rail more than women do and the high number of cars in households will reduce the probability of using light rail, also, current users of the public transit are more likely to use the light rail (Creemers et al. 2012).

Researchers study the variability and change in commuting patterns in cities and neighborhoods by considering different factors including wage (Wang, 2003; Y. Hu et al., 2016), race (Kain, 2004), income (Horner and Schleith 2012, Schleith and Horner 2014, Hu and Schneider 2017), gender (Kwan and Kotsev 2015, Sang et al. 2011, Kim et al. 2012), occupation (Sang et al. 2011, Kim et al. 2012), and land-use patterns (Wang 2000, 2003, Sultana 2002, Horner 2004, 2007, Hu et al. 2016, Hu and Schneider 2017). O'Kelly and Lee (2005) show that "in order to make jobs-housing balance policy an effective planning tool with which to achieve commuting efficiency, job characteristics must be considered". They show that level of excess commute and job/worker ratios are different for various occupations. Based on their models, journey-to-work flows for 14 occupational groups were produced. Overall, the authors find that workers in blue-collar jobs such as machine operation, precision production, transportation, and material moving are likely to make longer journey-to-work trips than those in white-collar jobs such as professional specialty, executive, administrative, and managerial jobs.

Hu et al. (2016) investigate commuting variability by wage groups in Baton Rouge between 1990 and 2010. They find that the lowest-wage workers have significantly shorter commute distance than the average. This might be because of their limited mobility like "low rates of vehicle ownership and high dependency on bicycling, walking, or transit that is often feasible only in the central city area" (Hu et al. 2016). In terms of commuting time, they observe that the highest-wage workers have less commuting time than overall workers do, in 1990 and 2000. Schleith and Horner (2014) study jobs-housing commuting balance and excess commuting for different income groups in Leon County, FL. They found that commuting distance increased over time and it is increased the most for low-income workers. Even for local scale, low-income commuters have longer commuting distance into the both dense city centers and sprawling jobs clusters along major roadways (Schleith and Horner 2014). Hu and Schneider (2017) investigate the relationship between commute behavior and income groups by considering workplace location in the Chicago metropolitan region. The authors suggest that when considering income and its relationship to commuting, it is important to consider workplace location too. The authors conclude that high-income workers are more likely to work in the CBD and less likely to use automobile because of the limitations of using automobile in the CBD. Thus, their automobile mode share would not be statistically different from the average automobile mode share of middle-income workers. It is important to know that the relationship between income and commute mode would vary by workplace location (Hu and Schneider 2017).

Owen and Levinson (2015) modeled the commute mode share of transit by applying continuous accessibility to jobs. Their results show that higher transit mode share and higher auto accessibility are associated to each other. However, higher transit mode share is associated with lower household income (Owen and Levinson 2015). Ransom and Kelemen (2016) reanalyzed the study by Bhattacharjee and Goetz (2012) regarding the effect of light rail system in Denver Colorado on highway traffic and growth of highway traffic. Ransom and Kelemen (2016) indicate several flaws in that study and suggest that light rail did not credibly reduce highway traffic and growth of highway traffic. They claim that Bhattacharjee and Goetz did not consider several issues in the light rail zones and outside of light rail zones in their analysis. Traffic in areas that are outside of light rail zones grew faster and they incorrectly claimed that it was causal. In addition, employment and population grew more slowly in light rail areas; so consequently, the traffic would grow more slowly than other parts of the Denver metropolitan area (Ransom and Kelemen 2016).

Given potential changes in household and firm location as a result of rail transit investments as well as commuting behavior and mode choice preferences exhibited by different income groups, it is reasonable to assume that changes to a city's public transportation system are likely to change the spatial distribution of firms and workers and hence commuting patterns. Given these potential changes, this research study will examine what kind of workers live and/or work in light rail -adjacent neighborhoods and how this together with commuting patterns in and out of these neighborhoods have changed over time (i.e., pre/post opening of a LRT line). Overall, the study explores the potential impact that light rail transit has on connecting people with jobs by studying the types of jobs (industry and wage level) adjacent to light rail transit and the types of jobs held by residents with access to the light rail system as well as commuting patterns in and out of transit neighborhoods.

CHAPTER 3: THEORY

Transportation and accessibility has been part of the discussion of economic geography explaining residential sorting of individuals based on their income categories and firm location decision-making across the urban areas. Theories regarding individuals' housing decision and firms' location decision have relied on the notion that highly accessible areas such as central business districts will generate the most demand. For this research, I will draw mainly upon two theories, bid-rent theory and public choice theory, to explain why I expect changes in both industrial and residential composition of the neighborhoods adjacent to the rail transit stations.

Bid-rent theory assumes that households and firms have a combined rent and transportation budget (Alonso 1960). As transportation costs increase, the amount available for rent is reduced. It predicts that higher income households will locate in the outskirts of the city where they can get a lot of land for their money while lower income households trade off greater living space for increased accessibility to employment. However, the theory does not account for the value of time, which is often assumed to be higher for higher income earners suggesting they would prefer to locate in accessible locations. For firms, Alonso (1960) predicts that retails and other establishments that sell directly to customers and are less land intensive will favor locations close to demand (i.e., the center). To office firms, travel costs are also important as its workers have to return to the office and hence such establishments are also likely to be in more accessible locations. Finally, industrial establishments, which require more land and only have to transport their goods one way will prefer to locate in the outskirts where land is abundant and cheap. Light rail and other transportation infrastructure improvements reduce the cost of transportation.

Hence, areas around light rail stops become important for firms and households who value the accessibility it brings, putting upward pressure on land and property values around it. The types of firms likely to pay the extra premium are those for which transportation costs and being close to the demand is important, that is, retail and service firms as well as office firms. For households, on the one hand, the theory would predict it to be lower-wage workers who value these locations as they have limited combined travel and housing budgets, but on the other hand, higher-income earners have higher opportunity costs in terms of value of time which may attract them to these more accessible areas. Hence, from a theoretical standpoint, the predicted outcome that which type of workers would reside in these areas is ambiguous.

On the hand, in ”The Great Inversion and the Future of the American City” by Alan Ehrenhalt (2012), he suggests that a demographic shift is going to happen in American Cities. He predicts that in a new wave of upper-middle-class white people will move to downtown areas and immigrants and working and middle-class African-Americans will move to suburbs. While city centers become safer, more young professionals without school-age children and affluent retirees move into the city centers. They scarcely buy large detached single-family houses far from the city center. At the same time good jobs, good schools, property value and safety of the suburbs attract more middle-class Afro-Americans and immigrants to the suburbs.

Public choice theory (Tiebout 1956) predicts that as the provision of public goods in a location changes (e.g., light rail), there will be a sorting of households across neighborhoods according to their willingness (and ability) to pay for these public goods. The resulting settlement pattern is segregation by characteristics of the households who demand the public goods (e.g., income, socioeconomic status, number of children, etc.). Hence, together with increase in property value in neighborhoods adjacent to light rail transit stations, I expect to see changes in sorting of residents according to their income and ability (as well as willingness) to pay for the accessibility and other amenity that light rail transit brings.

Based on these theoretical frameworks, I propose the following as a conceptual framework for my research. By improving transportation infrastructure in certain urban areas (e.g., light rail investment), and consequently increasing accessibility, attractiveness of these neighborhoods will increase. Firms, which are sensitive to transportation costs (with regards to the movement of people) and/or rely on being close to demand will demand these more accessible locations. I hypothesize that these will mainly be retail, service and office firms (as opposed to manufacturing or other more land intensive establishments mainly concerned with business-to-business interactions). Demand for these locations will also come from households who want to reduce their transportation costs. The increased demand for location close to light rail transit stations will put upward pressure on property and land values (and hence rents). This means that while both firms and households may enjoy lower transportation costs in these locations, they will be spending more on housing/land. For less productive firms, this may result in smaller stores and office buildings, or they may have to move to other locations with lower rents. Hence, depending on the initial industrial composition of the neighborhoods adjacent to the rail transit stations, we expect to see change in the type of firms residing there.

First, we may see the industrial composition and land use change from more land intensive business operations to less land intensive businesses where the movement of people is important to the firms. This is the focus of this research. Second, we may experience a shift from less productive to more productive firms. Some opponents to light rail transit and transit-oriented development have raised fears of what has been termed "commercial gentrification", which suggest that as rents and land values in rail transit-adjacent neighborhoods increase, independent businesses are being displaced by chain stores and other larger firms that are able to pay the additional premiums of being located in these areas (Yoon and Currid-Halkett 2015). These types of changes in ownership structure of firms in rail transit neighborhoods are outside the scope of this research.

As for workers residing in these neighborhoods, particularly lower-wage workers will face two options if property values and rents increase in the neighborhoods adjacent to the rail transit stations. The first option is to downsize and the second is to move out. The job accessibility experienced by low- vs. high-wage workers also depends on the industrial composition and land use of the neighborhoods adjacent to the rail transit stations. If dominated by office firms, which are typically associated with higher paying white-collar jobs, these locations will become particularly attractive to higher-wage workers likely to hold these jobs. If dominated by retail and service firms, typically associated with lower paying occupations, these locations become important for the accessibility of lower-wage workers. With combinations of both office and retail/service jobs (which is the most likely outcome), the outcomes are likely to vary along a given rail transit line or depending on housing availability may be dominated by those workers with a higher willingness and ability to pay.

With potential changes in both the types of firms (hence types of jobs) and workers in the neighborhoods adjacent to the rail transit stations, we ultimately expect to see changes in commuting patterns. This process is summarized in Figure 1, which will serve as a conceptual framework for this research.

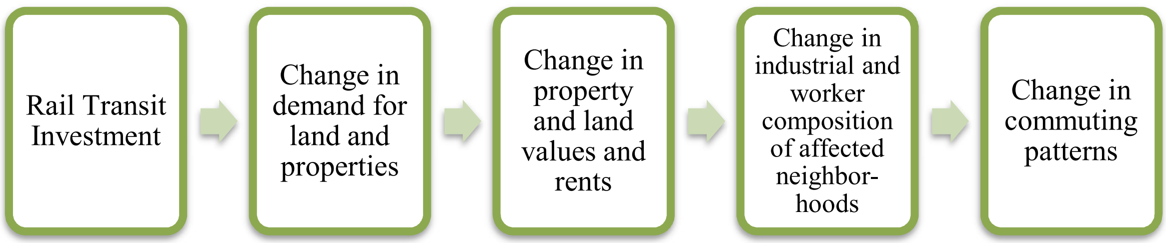

FIGURE 1: Conceptual framework on the link between rail transit investments and industrial and worker composition in affected neighborhoods

CHAPTER 4: METHODS AND DATA

To address the first research question, to what extent does rail transit affect the industrial and wage composition of jobs and workers in neighborhoods adjacent to fixed rail stations, I apply difference-in-differences estimations to a series of outcome variables measuring industrial and wage composition. Difference-in-differences (DID) is a technique used to estimate changes an outcome variable after a treatment (e.g., rail transit investments) both in the population affected by treatment (the treatment group) and a comparable population that has not received the treatment (the control group). The most important assumption of DID is the parallel trend assumption. That is, the pre-treatment outcomes for the treatment and control groups have a similar (parallel) trend (Gertler et al. 2011).

There are different approaches to identify treatment and control group neighborhoods in an urban area. In studies of property value, demographic and socioeconomic changes in neighborhoods near transit stations, most studies use a Euclidean distance buffer of 0.25 up to 1 mile (Baum-Snow and Kahn 2000, Chalermpong 2007, Lin and Hwang 2003, Des Rosier et al. 2010, Dube et al. 2011) to identify the treatment area adjacent to rail transit stations. Other studies use network-based distance (Diao et al. 2017) which is more realistic but more difficult to perform.

Since rail transit stations are not placed at random, we cannot use a randomized approach to select control neighborhoods. Hence to identify a control group, some scholars have used a wider distance band to find controls, i.e., neighborhoods close to the treated ones but further away from the stations (Gibbons and Machin 2005, Diao et al. 2017). The limitation of this approach is that neighborhoods further away from a station might not necessarily be similar to the treatment group in terms of land-use (e.g., more mixed-use development near stations while more single-family housing further away) and the parallel trend assumption may therefore not hold. Another way of choosing the control group involves using matching techniques such as propensity score matching (PSM) which aims at finding controls that have minimal differences in the distribution of a set of observed characteristics between the treatment and control group (Gertler et al. 2011). In this study I adopted a strategy similar to Billings (2011), Mayer and Treiven (2017), Donaldson (2018) and Heilmann (2018) who use the non-built portion of the light rail network as the control group. Large infrastructure projects such as light rail lines are assigned to neighborhoods based on current or future expected demand (Heilmann 2018). Usually rail transit planners have a specific goal to address for building light rail transit and neighborhoods are selected in order to respond to that specific goal. Therefore, the entire proposed light rail alignments must have some similarities to be picked for the placement of light rail transit system. For example for Charlotte, Billings (2011) argues that these neighborhoods without the light rail are similar in characteristics to the treatment neighborhoods but did not receive rail transit stations during the study period. In Charlotte, all three alignments contain a number of similarities; they connect downtown to residential neighborhoods, and existing transportation corridors have been used to determine the placement of the LRT alignment.

To address my first research question, I estimate the effect of light rail transit (LRT) on employment change and the type of jobs and workers in a neighborhood using the following difference-in-differences model (all estimations were performed in Stata/SE 14):

$$Ln(Emp_{i,t}) = \alpha + \beta_1 T_{i,t} + \beta_2 Post_{i,t} + \beta_3 T_{i,t} \times Post_{i,t} + \beta_4 X_{i,t} + \varepsilon_{i,t} \qquad (1)$$

where i denotes the block and t denotes the year. The dependent variable for the models using the WAC data is the natural log of employed workers or employment, $Ln(Emp_{i,t})$, in block i at time t. For the models using RAC data, the dependent variable is the natural log of total number of workers residing in block i at time t, $Ln(Res_{i,t})$. $X_{i,t}$ is a vector of controls including the distance to the city center, dummy for recession, and share of workers in each supersector (that will be explained later in this section). $T_{i,t}$ is an indicator for block i belonging to the treatment group (1 if in the treatment group and 0 if in the control group), $Post_t = 1$ indicates time periods after the opening of the light rail in 2007, β_3 is the difference-in-difference estimator given by the interaction of $T_{i,t}$ and $Post_t$. It measures the amount of change in the outcome between the treatment and the control blocks after opening of the light rail (the treatment) and is hence the coefficient of interest.

Based on the strategy of using the non-built portions of the light rail network as my control group, the treatment group is the South line (the first part of the LYNX Blue line) running from downtown towards South Boulevard opened in 2007. The control group include two lines, the extension of the South line, which runs to the north to the UNC Charlotte main campus that was opened in 2018 (called the Blue Line Extension) and the planned southeast line (the Silver line) running from the town of Matthews to the city center. Hence, the controls are the blocks within a quarter mile of the stations of the Blue

Line Extension, which opened in 2018, and the planned Silver Line and the treatment is the blocks within a quarter mile of the South Line stations (Figure 2).

In order to have a feasible set of industries to analyze, I group industries into modified NAICS supersectors from the Bureau of Labor Statistics' (BLS) Current Employment Statistics (CES) program. These modified supersectors include (1) Goods, production, transportation, and utilities; (2) Trade, leisure and hospitality; (3) Information, finance and real state, professional and business services; (4) Education and health services; (5) Other services; and (6) Government and public administration.

To study changes in shares of different workers in neighborhoods affected by light rail transit investments, LODES' predetermined wage categories are used. The two groups of interest for this study is low-wage workers (jobs with earnings $1250/month or less) and high-wage workers (jobs with earnings greater than $3333/month).

To address my second research question, i.e., which types of workers are commuting to and from these neighborhoods and how that has changed over time, I apply a couple of empirical approaches. In addition to analyzing trends using exploratory data analysis, I use ordinary least square (OLS) regression models to estimate the association between the share of workers commuting into LRT neighborhoods and the characteristics of workers in the origin neighborhood. For this purpose, I estimate the following equation (all estimations were performed in Stata/SE 14):

$$y_{i,t} = \alpha + \beta_1 Low_{i,} + \beta_2 Med_i + \beta_3 Ind1_i + \beta_4 Ind2_i + \beta_5 OriginLR_i + \beta_6 Dist_i + \beta_7 Year_i + \varepsilon_i \quad (1)$$

where i denotes the block and t denotes the year. $y_{i,t}$ is the percentage of commuters coming from block i to a light rail transit block for job. $Low_{i,t}$ is the percentages of commuters in low-wage category going from block i to a light rail transit block, with high-wage category as reference group. $Med_{i,t}$ is the percentages of commuters in medium-wage category going from block i to a light rail transit block, with high-wage category as reference group. $Ind1_{i,t}$ and $Ind2_{i,t}$ is the percentages of commuters in industry category 1 and 2, respectively, going from block i to a light rail transit block with industry category 3 as reference group. $OriginLRT_i$ is a dummy variable which takes the value of 1 if block i is another light rail transit block. $Dist_i$ is the distance from origin block (i) to its destination light rail block. *Year* is a series of year-specific vectors to account for year fixed effects. Finally, ε is a vector of unobserved errors.

4.1: DATA

The data used for this study comes from the Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES) dataset from the Bureau of Labor Statistics (BLS) from 2002 to 2014. In order to have sufficient amount of observations before and after the light rail transit opening, Charlotte's Blue Line was chosen as it opened in 2007. The LODES data is organized in three groups (The LODES Version 7.1 used for this study is enumerated with 2010 census blocks): Residence Area Characteristic data (RAC) which jobs are totaled by home (or origin) census block, Workplace Area Characteristic data (WAC), which jobs are totaled by work (or destination) census block, and Origin-Destination data (OD), which connects the two. These files contain job totals, jobs by age, income category and industry sector and more. These three groups of datasets include some other variables that are not used in this study such as race, ethnicity, educational attainment, and sex. The reason that I do not incorporate these into the analysis are because they are only available for years 2009 and after and are made available through a Beta release. Regarding the quality of the LODES data, these data are tabulated and modeled administrative data. Since they are not based on probability sampling, measuring of sampling error is not applicable. However, non-sampling errors may still exist. These errors can be due to “misreported data, late reporters whose records are missing and imputed, and geographic/industry edits and imputations.” (ACI Media Release, 2017)

To classify workers into different industry categories and wage groups I am bound to the classification reported in the LODES data. There are three industry categories in the LODES data, including: Goods producing industry sectors (Industry 1); Trade, Transportation, and Utilities industry sectors (Industry 2), and; All Other Services industry sectors (Industry 3). The three wage categories are: jobs with earnings of $1,250/month or less (Low-wage jobs); jobs with earnings of $1,251/month to $3,333/month (Medium-wage jobs), and; jobs with earnings greater than $3,333/month (High-wage jobs).

Given how the data is reported, census blocks (the smallest geographic unit provided by the US Census Bureau) are my geographic unit of analysis and are used as a proxy for neighborhoods. To define neighborhoods that are in proximity to light rail transit, a buffer of a quarter of a mile (0.25 miles) is applied around each station and all blocks that intersect the station’s buffer are considered adjacent to the station. This distance of 0.25 mile has been used because it is considered the maximum distance that people are willing to walk to use public transportation for their commute (Urban Mass Transportation Administration 1979). I also tested a buffer of 0.5 mile for my analysis but the results were qualitatively the same. Thus, I just present the results for the more conservative definition of a quarter of a mile.

For my first research question, I use both the RAC and WAC datasets. Data for location of the rail transit stations comes from the City of Charlotte. Census block shapefiles of Mecklenburg County, NC, were collected from the U.S. Census Bureau's TIGER/Line shapefiles (United States Census Bureau 2019). In order to be able to study changes pre/post opening of the light rail, I use all three lines and divide them to treatment and control groups (Figure 2).

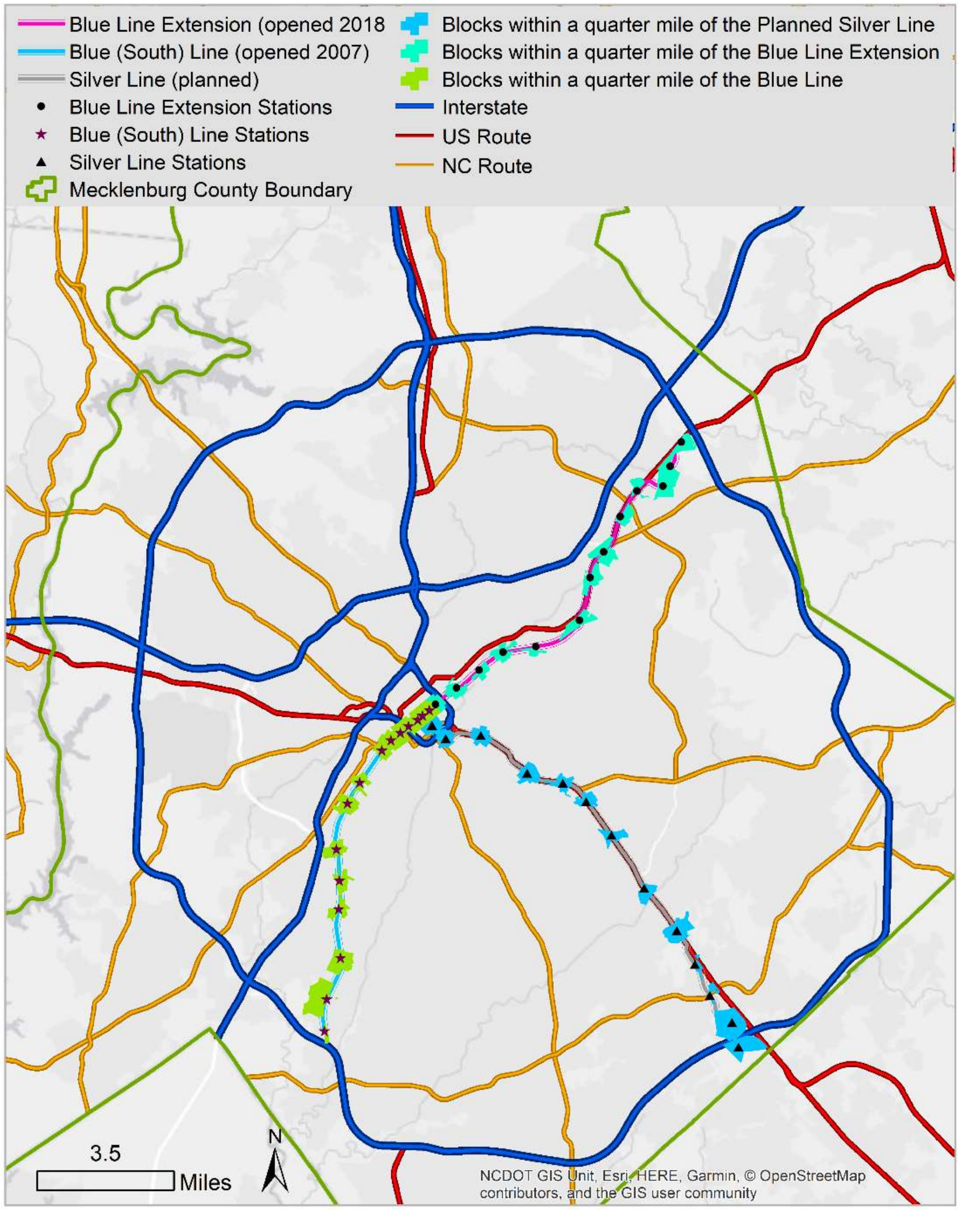

FIGURE 2**:** Map of Mecklenburg County with the South line (LYNX Blue Line) stations, Northeast Line (Blue Line Extension) stations, and Southeast Line (Silver Line) stations, and blocks within 1/4 mile from each station

For my second research question, I use the OD dataset. In order to be able to study changes before and after the opening of the LRT, only the original Blue (South) Line and the census blocks within a quarter of a mile of each of its stations have been used for analysis (Figure 2). My analysis focuses on three groups of commuters: (i) those who work in LRT blocks and reside in other blocks; (ii) those who reside in LRT blocks and work in other blocks; and, (iii) those who both work and reside in LRT blocks.

The data, however, has some limitations. As mentioned earlier, the predefined wage categories are jobs with earnings of $1,250/month or less (Low-wage jobs); jobs with earnings of $1,251/month to $3,333/month (Medium-wage jobs), and; jobs with earnings greater than $3,333/month (High-wage jobs). The highest wage category, $3,333/month translates to approximately $40,000/year, which is just above the per capita income of Charlotte ($34,687) and below the median household income of Charlotte ($58,202) as of 2017 (Census 2019).

Thus, both low- and medium-wage categories are below the mean and median income and the high-wage category is above the per capita income in Charlotte. In addition, these predefined wage categories does not consider inflation over time. However, we assume that both the treatment and the control groups where subject to these macro-level factors in a same way and since we are interested in the difference between the treatment and the control groups and changes in the movement of workers and residents into these two groups, this limitation of the data do not affect this comparison.

Table 1 shows a summary statistics of the study area. In WAC, the average number of blocks in the treatment and control groups per year is similar. Average number of employment in the treatment block is higher than the control block. Other variables are also different, specifically, average number of jobs in super sector 3 (Information, finance, professional and scientific services) is much higher in the treatment block. Average number of high-wage workers is also much higher in the treatment block.

In RAC, the average number of blocks in the treatment and control groups per year is not similar. However, other variables have slightly similar average numbers in blocks in both treatment and control blocks.

TABLE 1: Summary statistics

	Average number in blocks within Mecklenburg	Std. Dev.	Average number in treatment blocks	Std. Dev.	Average number in control blocks	Std. Dev.
Blocks in WAC	5722		137		128	
Employment	96	404	454	910	156	683
Low-wage workers	22	76	78	134	36	100
Medium-wage workers	35	141	130	239	57	223
High-wage workers	39	229	246	595	63	428
Jobs in supersector 1	24	147	39	161	12	32
Jobs in supersector 2	19	88	69	125	29	61
Jobs in supersector 3	32	193	288	722	33	120
Jobs in supersector 4	15	226	9	28	33	306
Jobs in supersector 5	3	16	12	48	3	11
Jobs in supersector 6	2	99	35	322	45	567
Blocks in RAC	8992		54		119	
Residents	44	85	52	66	38	86
Low-wage residents	11	21	11	14	11	27
High-wage residents	16	32	17	22	16	37
Medium-wage residents	17	36	24	37	11	25
Residents in supersector 1	9	18	9	12	7	15
Residents in supersector 2	10	20	10	13	9	24
Residents in supersector 3	15	28	22	32	13	28
Residents in supersector 4	8	16	8	10	7	16
Residents in supersector 5	1	3	1	2	1	3
Residents in supersector 6	1	3	1	2	1	3

Table 2 shows some descriptive statistics of the treatment group, control group, and Mecklenburg County in 2014. Since this data is just available from 2009 and forward from the American Community Survey (ACS), I just include 2014, the end year of my study period. In addition, it should be noted that the data is not available at the census block level.

Hence in order provide a brief description of the differences between these different areas, I have used block group level data. This means the statistics in Table 2 are based on areas which are larger than the areas used in the remaining statistical analysis which are based on census blocks.

The statistics in Table 2 show that the treatment and control group have very similar in terms of demographics, measured by the share of White and Black population, where the share of Black residents are on average lower in the treatment and control group compared to the county. In terms of socioeconomic attributes including mean of median household income, median value of owner-occupied housing units, and share of renters, the two groups are also very similar but generally different from the county as a whole but with some similarities.

TABLE 2: demographic and socioeconomic attributes of treatment and control groups versus Mecklenburg County in 2014

	Treatment group	**Control group**	**Mecklenburg County**
White population	74.5%	74.0%	57%
Black population	18.9%	17.1%	30.9%
Median household income	$46,925	$49,221	$56,472
Median value of owner-occupied housing units	$166,840	$184,937	$181,800
Renters	34.3%	30.8%	41.3%

Data source: 2014 ACS 5-year estimates at block group

CHAPTER 5: STUDY AREA

For this study, Mecklenburg County, NC, with its county seat the City of Charlotte, and its LYNX Blue Line light rail has been chosen for analysis. Charlotte is the largest city in the state of North Carolina with 872,498 residents as of 2018 (U.S. Census Bureau 2019a). According to the census, Charlotte had the fifth largest numeric increase in population between 2017 and 2018 in the country (U.S. Census Bureau 2019b), ranking it the sixteenth largest city in the United States (U.S. Census Bureau 2018). In 2015, Charlotte obtained the largest influx of millennials than any other city in the United States with a 10,707 net gain (Miller 2017). This influx of millennials continued in 2017 with a 5,060 net gain, making it the sixth largest influx of millennials (Geler 2019). Furthermore, in 2018, Charlotte ranks fourth among best cities for young professionals in the United States (Jensen 2018). Charlotte is home of a large banking industry and several Fortune 500 companies including Bank of America, Nucor, Duke Energy, Sonic Automotive, and Brighthouse Financial (Fortune 2019). The banking industry makes Charlotte the second largest financial center in the US after New York and it has one of the highest median wages in the region (Kozar 2010). Another large industry in Charlotte is finance, insurance, and real estate (FIRE), and headquarters of several national corporations are located in Charlotte (Bacot 2008).

In terms of the industrial composition of Mecklenburg County, as of 2015 the largest share of employment is in to finance and insurance followed by retail trade, administrative and support and waste management and remediation services, Professional, scientific, and technical services and finally, accommodation and food services (Khabazi 2018). Education is another large economic sector in Mecklenburg County due to a large public-school system and a regional state university (Bacot 2008). Universities and colleges in the county include University of North Carolina at Charlotte, Davidson College, Queens University, Johnson & Wales University, Wake Forest University (School of Business) Charlotte Center, Johnson C. Smith University, Southern Evangelical Seminary, Central Piedmont Community College, and Belmont Abbey College.

The county's airport, Charlotte-Douglas International Airport, is the eleventh busiest airport of the United States in 2019 ranked by passenger traffic and fifth by aircraft movements (ACI Statistics April 2017). It is also the second hub for American Airlines after Dallas/Fort Worth (Portillo 2014).

Since banking industry is one of the largest industries in Charlotte, it was hard hit by economic recession in 2008. The impact of the recession included lots of unemployment in the region. However, the diversity of employment in Charlotte helped it to sustain even at the time of distress of economic recession (Kozar 2010).

As you can see in Figure 3Charlotte's road network includes an inner ring, outer beltway, highways crossing through the city, and major arterials that radiate out from and across the city. Highway I-277 has formed a boundary around the center city and I-485 has encouraged more developments towards the suburbs and formed an outer ring around the city. Other important highways include I-77 to the north; I-85 to the northeast; Hwy 74 to the southeast; I-77 to the south; and I-85 to the west.

Charlotte has had segregated communities in the inner city's four wards in twentieth century (Ingalls and Heard 2010) and has seen a gradual displacement of Black communities by White suburbs during last centuries (Ingalls and Heard 2010). It continues to be one of the most segregated cities in North Carolina (Henderson 2018).

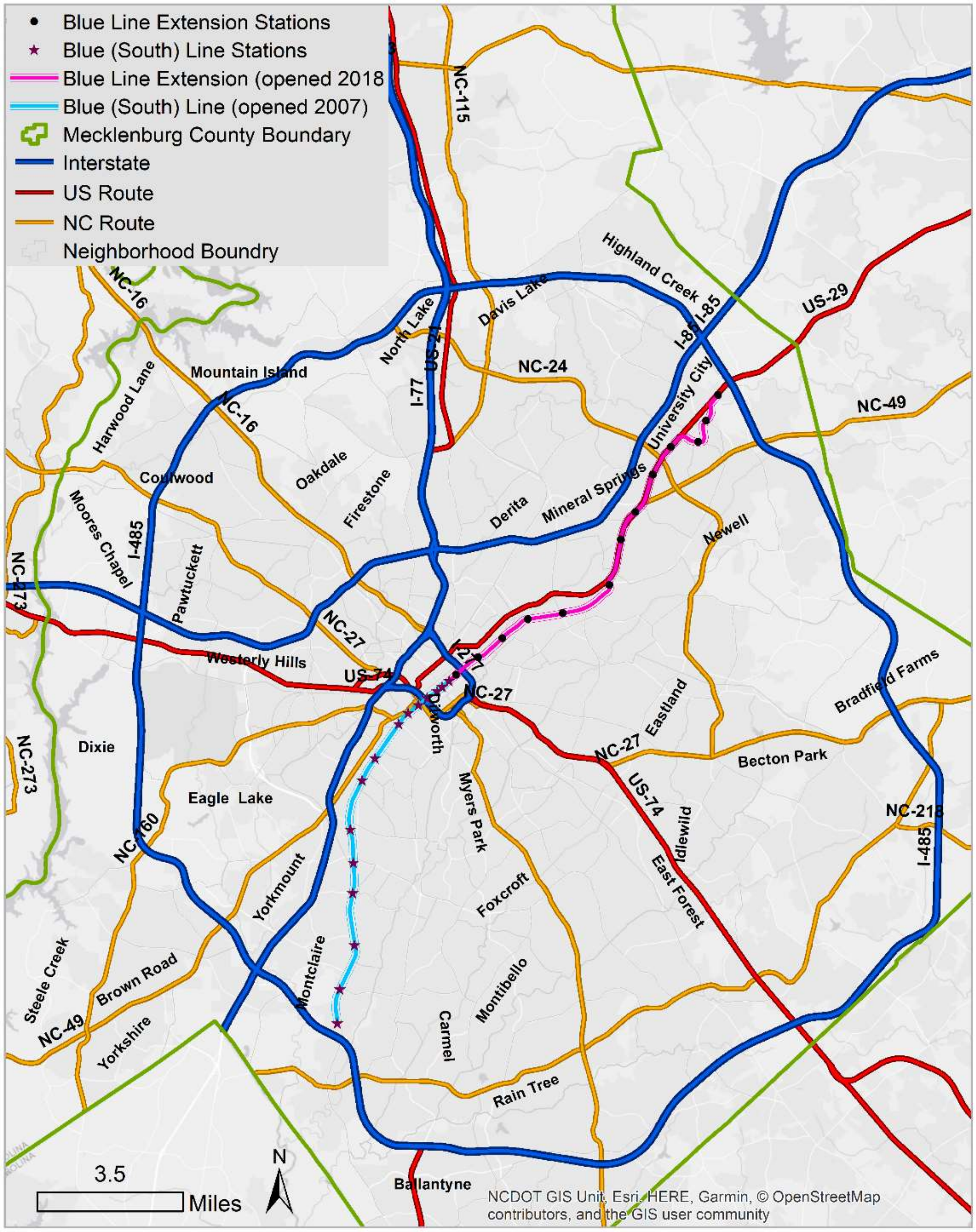

Figure 3: Charlotte, NC

Like other cities in the nation, Charlotte has seen an increasing interest among young professionals in the urban core of the city and its adjacent neighborhoods. In Charlotte, the neighborhoods adjacent to the center city that used to have a large share of minority and low-income residents now see rapid rising property values. These neighborhoods in Charlotte include Plaza Midwood, NoDa, Cherry, Wilmore, Belmont, Seversville, Wesley

Heights, Grier Heights and Druid Hills (Dunn 2017). In the last decade, these neighborhoods have seen an influx of more affluent, mainly white, residents (Dunn 2017). Many of these neighborhoods were the place of textile mills that gradually have been reusing as commercial, mixed use, office, and residential land use (Moore and Ingalls 2010). Then these neighborhoods have experienced light rail investments, the original Blue (South) Line that opened in 2007, which runs through South End, including Wilmore, and the Blue Line Extension, which opened in 2018, which runs by Belmont and NoDa.

The city's public transportation consists of a bus network and two light rail lines. The first light rail line in Charlotte is the LYNX Blue Line (also known as the South Line) which opened in 2007 with 18.9 miles length, 26 stations, and 11 park and ride locations. (Website of City of Charlotte 2019). It runs from the southwest part of the county to the central business district (CBD). In 2018, the city's second line opened, the Blue Line Extension, which connects the original line to the University of North Carolina at Charlotte (UNCC) campus in the northeastern part of the city. In November 2016, The Metropolitan Transit Commission approved the LYNX southeast light rail alignment (the "Silver line") into the city's 2030 Transit System Plan, which will run from southeast to Center City of Charlotte. The line is expected to open in 2030 and will be 13.5 miles long with 13 stations (including 8 - 10 park and ride locations) (Website of City of Charlotte 2019).

CHAPTER 6: RESULTS

6.1: QUANTIFYING LIGHT RAILS EFFECT ON INTRAURBAN DISTRIBUTION OF ECONOMIC ACTIVITY

As noted earlier, in this section, I am going to study the effect of light rail investments on changes in industrial and wage composition of light rail-adjacent neighborhoods as well as characteristics of workers living in these neighborhoods.

To compare the trend in employment by census block in the treatment and the control groups, I take the natural log of the mean number of employed residents (in the case of RAC data) and the mean number of workers (in the case of WAC data) per census block for both the treatment and the control groups from 2002 to 2014. Figure 4(a) shows the natural log of the mean employment per census block for workplace (WAC) data and figure 4(b) shows the natural log of the mean number of workers residing in each census block for residence (RAC) data. The vertical line shows the opening year of the South Line in 2007. Figure 4(a) shows the treatment group has a larger number of workers per census block compared to the control group from 2002 to 2014. However, the treatment and control group appear to exhibit similar trends across the entire time period. Figure 4(b) shows that the treatment group also has higher levels of workers by the place of residence. While there is no real difference in trends between the two groups prior to the opening of the South Line, there is a stark difference in trends after the introduction of the South Line in 2007. Starting in 2008, the treatment group has experienced significant growth in the number of workers residing in these neighborhoods while the control group appears to have stayed at similar levels on average as in the pre-2007 period. The increase in the treatment group is likely due to the increase in both housing supply and demand in these neighborhoods. There is an apartment boom in the downtown area with more than 2,000 luxury units requesting the highest rents in the city (Portillo 2017). More apartment units are being built along the light rail stations due to its easy access to public transportation and mix of commercial land-use (Sealey 2018; Smoot and Lindstrom 2019).

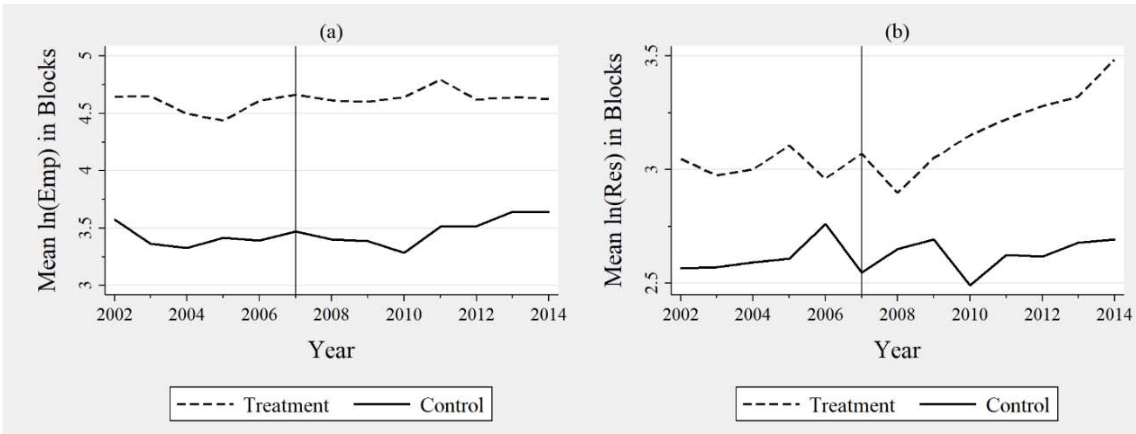

FIGURE 4: (a) Mean natural log of workers' jobs per census block in treatment and control groups (WAC data) (b) Mean natural log of residents' jobs per census block in treatment and control groups (RAC data)

To investigate where the concentration of low-, medium-, and high-wage workers are in Mecklenburg County, we measure local spatial autocorrelation in residence location of all workers in Mecklenburg County in the base and terminal year of the study period using Getis-Ord's G-statistics (1992). Figures 5 and 6 show significant clusters of the three wage categories in Mecklenburg County in 2002 and 2014 respectively. A visual inspection of the workers' residential location hot spot analysis over time suggests a decline in locations of significant clusters from 2002 to 2014 for all three wage categories. In 2002, there are some scattered clusters of residential location of low- and medium-wage workers in Mecklenburg County mostly in east and southwest. High-wage workers have more defined clusters in the south and northeast portions of Charlotte, meaning more concentration of this wage category in these areas and a clear cold spot in center of Charlotte that means there are very low number of high-wage workers living around downtown area in 2002. A clear division of low- and high-wage workers appears on these maps. Studying closely the location of the South line light rail, we observe significant clusters of high-wage workers in the neighborhoods adjacent to the light rail stations, both in 2002 and 2014. That is, even before the opening of the light rail it appears that the light rail investment targeted connecting high-wage workers with their potential places of work more than connecting low-wage workers with lower-wage jobs.

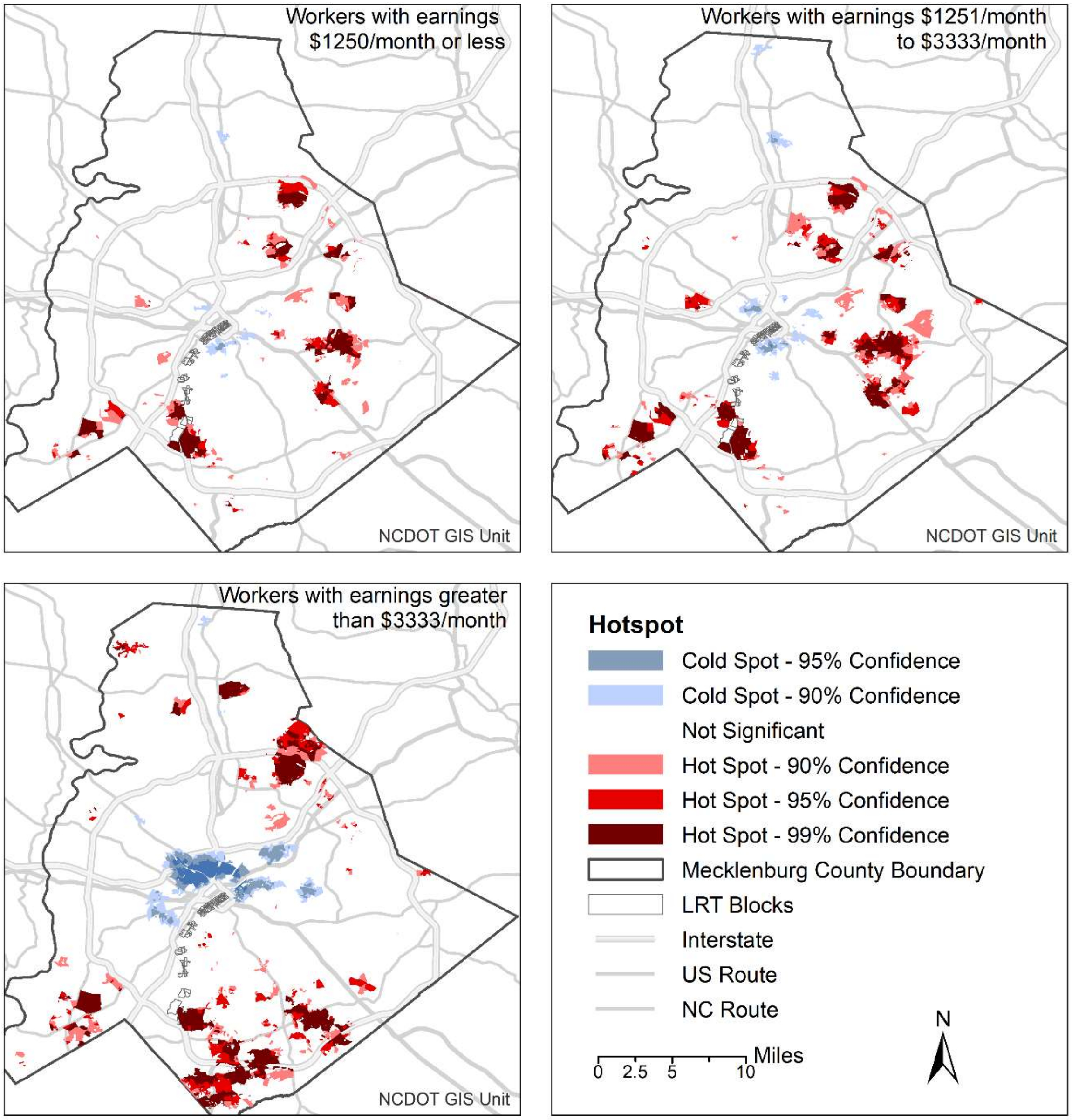

FIGURE 5 Hot spot analysis on residential location of those who work in Mecklenburg County by wage category in 2002

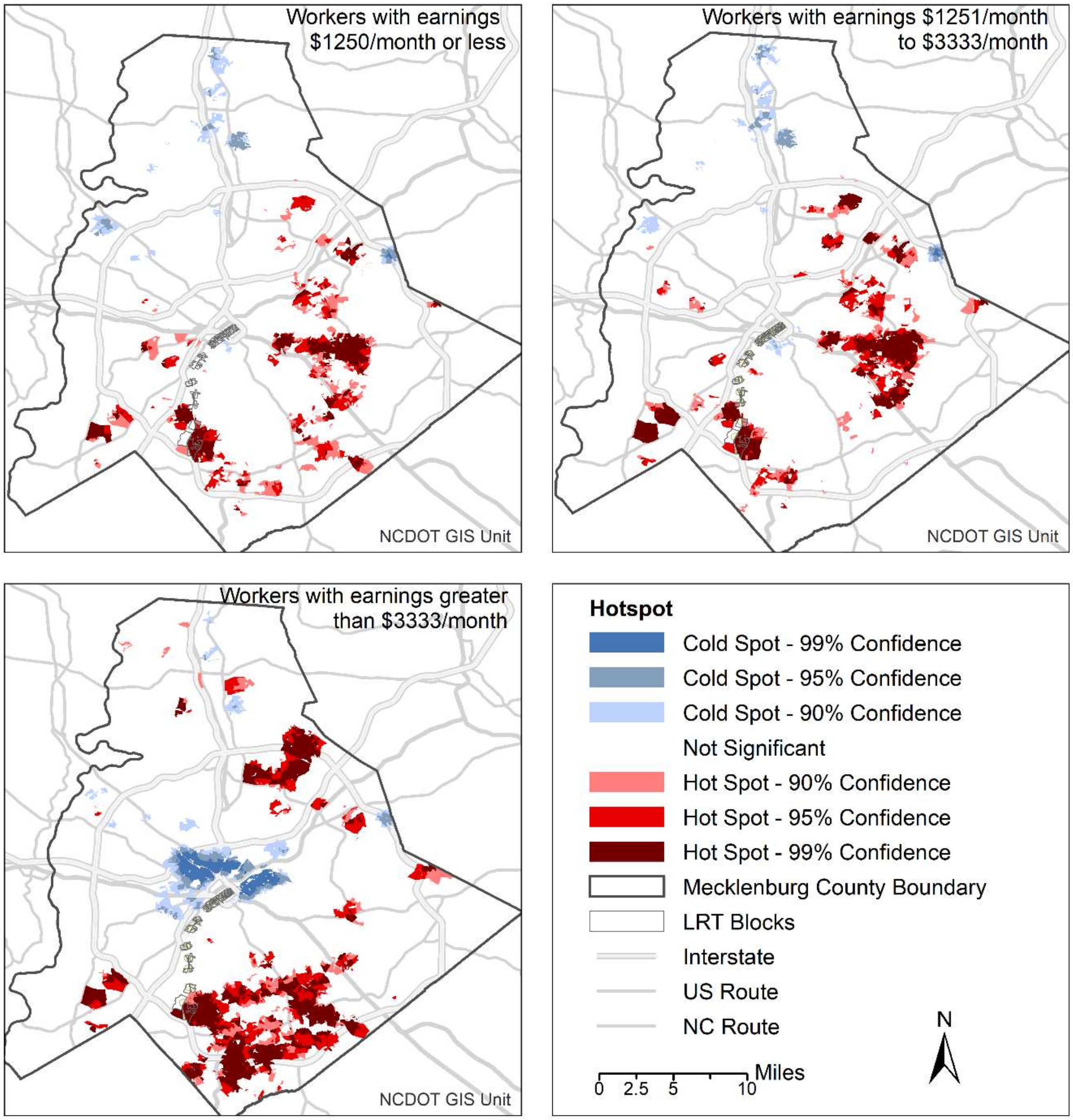

FIGURE 6 Hot spot analysis on residential location of those who work in Mecklenburg County by wage category in 2014

To assess whether there is a statistically significant change in the trends of employment and residential location of workers after the opening of the light rail, I estimate the model outlined in Equation (1). Table 3 presents the results of these estimations for both the WAC and RAC datasets. First, the model is estimated without the vector of control variables (Model 1). As expected from Figure 4, the coefficient for the treatment variable is positive and significant for both the WAC and RAC datasets. This indicates that the number of jobs and workers is higher in the treatment blocks than the control blocks for workers and residents. Nonetheless, the difference-in-difference estimator (Treatment*Post-2007) suggests there is no significant difference in trends in neither the number of jobs (WAC) nor the number of workers residing in the treatment blocks (RAC) after the opening of the South Line in 2007.

TABLE 3: DID estimation results for both WAC and RAC datasets

	WAC		**RAC**	
	DV: ln(Emp)		**DV: ln(Res)**	
Variables	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Treatment	1.153565***	1.093073***	0.397769***	0.4902437***
Post-2007	0.0677291	-0.0043601	0.0017124	-0.0064403
Treatment * Post-2007	0.0158822	0.0837891	0.1696705	0.1763839
Distance to City Center		0.006111		0.0651241***
Recession		-0.0768987		-0.0579615
Share of supersector 1		0.0209494**		-0.0304741
Share of supersector 2		0.0263968***		-0.0282257
Share of supersector 3		0.0323738***		-0.0219348
Share of supersector 4		0.0320941***		-0.0301246
Share of supersector 5		0.0186746*		-0.0268571
Share of supersector 6		0.0514099***		-0.0225119
Intercept	3.413135***	0.6625276	2.619207***	4.916511*
N	3,437	3,437	2,240	2,240
AIC	13827.11	13607.99	7930.74	7841.639
Adjusted R^2	0.0935	0.1514	0.0262	0.0675

Note: Significant at the ***1%, **5%, *10% significance level.

In the second models for WAC and RAC, I add the distance of each census block to the city center, a dummy for the recession in 2008, and the share of workers in each of the supersectors outlined in Section 4. For Model 2 in WAC and RAC, the number of jobs and workers in the treatment blocks are higher than the control blocks, however, there is no significant increase in the number of jobs in the treatment group after the opening of the South Line. For the place of work model (WAC), the distance to the city center and the dummy variable for the recession are not statistically significant. However, the coefficients for the share of all supersectors are positive and significant with the largest increase in jobs in both the treatment and the control blocks attributed to supersector 6 (Government and public administration) followed by 3 (Information, finance and real state, professional and business services) and 4 (Education and health services). For the place of residence model (RAC), distance to the city center is positive and significant implying a greater concentration of residents further from the city center in the control and the treatment group combined. However, none of the supersectors is statistically significant suggesting that there is no particular industry sector workers that has contributed to the increase in residents in neither the treatment nor the control neighborhoods during this time period.

Thus, the overall results show that the treatment group has had a prior advantage in number of jobs even before the introduction of the light rail compared to the control group. An important assumption for the difference-in-difference approach is the parallel trend assumption that the treatment and control group exhibit similar trends in the dependent variable before the treatment. That is the dependent variable for the treatment group (hypothetically) would grow at a similar rate as for the control group in absence of the treatment, which is the opening of the light rail line in my case. To verify the validity of the control group, I adopted the approach suggested by Galiani et al. (2005) and Wan et al. (2016) by separately estimating the two dependent variables from Table 3 only on the data between 2002 and 2007 for the treatment and the control group with including dummy variables for the year's fixed effects from 2003 to 2007 with 2002 as a reference category. Then I performed a significance test on the difference between the coefficients of yearly dummies of the treatment and the control groups to see whether they are significantly different. I performed this test for both WAC and RAC datasets. As presented in Table 4, no significant difference is present between the two groups for either one of the years included which implies that the common trend assumption stands for both WAC and RAC and suggests that the treatment and the control groups do not have any divergence before the treatment, and the control group is a valid control group.

TABLE 4: Test for difference in pre-treatment years fixed effects

	WAC			**RAC**		
Year dummy	**Treatment**	**Control**	**p-value**	**Treatment**	**Control**	**p-value**
2003	0.039392	-0.175334	0.4448	-0.04534	-0.026274	0.9524
2004	-0.103134	-0.243048	0.6229	-0.027312	0.0224271	0.8771
2005	-0.150048	-0.181488	0.9136	0.0544317	0.0020124	0.8694
2006	-0.045381	-0.210937	0.5701	-0.065136	0.1415372	0.5145
2007	0.0725302	-0.129567	0.4814	0.034536	-0.119229	0.6416

Thus far, it is clear that the number of jobs in the treatment group has been higher even before the opening of the light rail. It is expected that cities invest in the LRT to connect people with employment centers. Literature indicates that housing demand is higher in the LRT neighborhoods by young childless high-skilled professionals (TCRP

2004), and the type of jobs that these workers would hold are more high-skilled jobs with higher earnings. Thus, cities can maximize their benefits by connecting these groups of residents to high-earning jobs. This is also a group of residents that are more likely to be willing to pay for public amenities and afford higher property values associated with such amenities, hence being able to contribute to the increased property tax revenues.

To better understand the industrial and wage composition of the treatment and the control groups for the workers (WAC) and the residents (RAC) I explore the share of each supersector and wage categories in both groups separately. Figure 7 shows the average number of jobs in different supersectors in the treatment and the control group from 2002 to 2014 in the workplace (WAC). There is a noticeable difference in the industrial composition and land use of the treatment and the control groups. Almost 70% of treatment blocks consist of jobs in information, finance, real estate, professional, and business services (supersector 3), and only 30% of the jobs are in the other industries. In the control group, supersector 3 covers just 20% of the jobs and it declines as time passes, while government and public administration jobs jump in 2012 to cover almost 50% of the jobs in the control group.

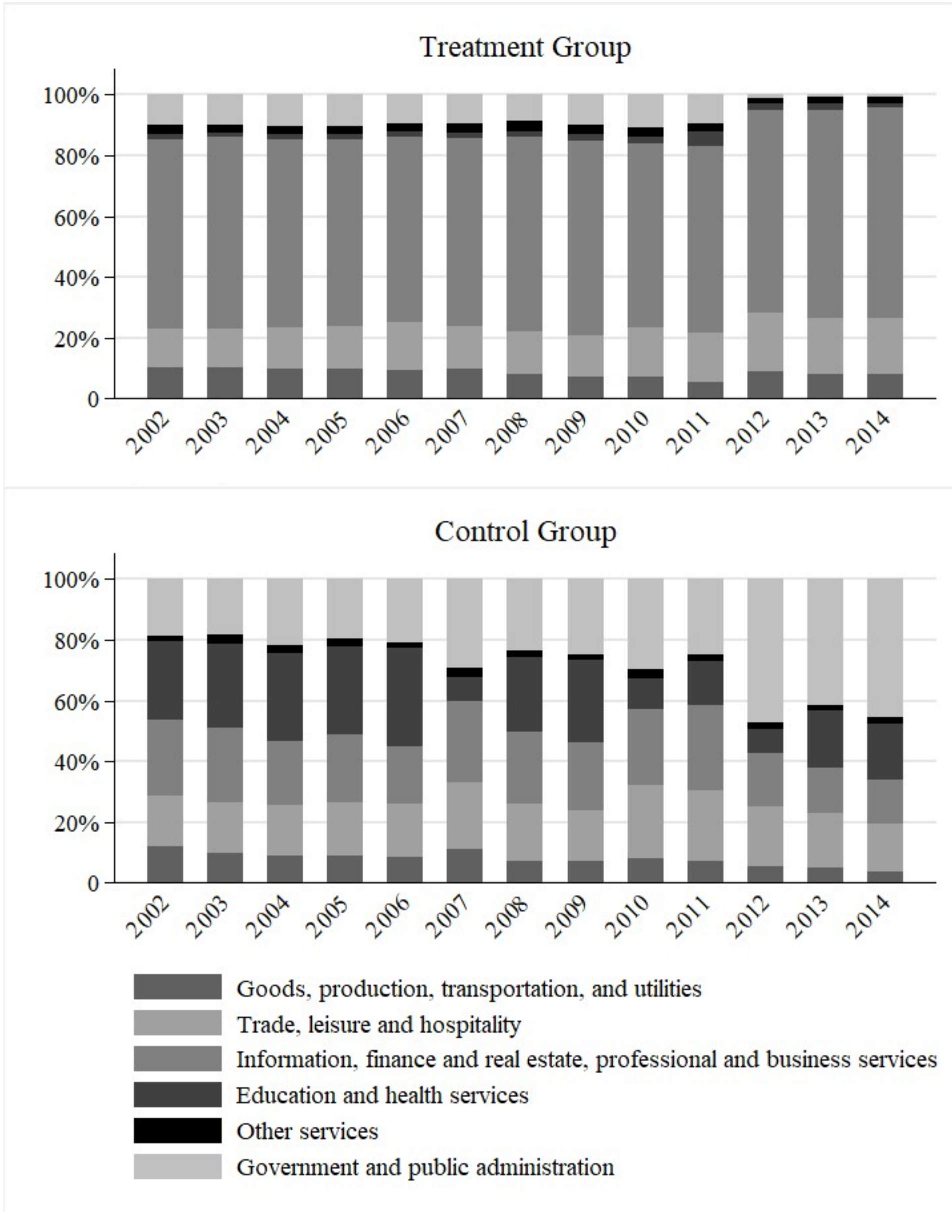

FIGURE 7: Share of jobs by industry supersectors for workplace (WAC data)

The industrial and wage composition of residents in the treatment and the control groups (RAC) do not face any specific change except a small increase in the share of supersector 3 in the treatment group and a small decrease in the share of supersector 1

(Figure 8). Comparing the treatment to the control group, there is a slightly higher share of supersector 3 in the treatment than the control blocks.

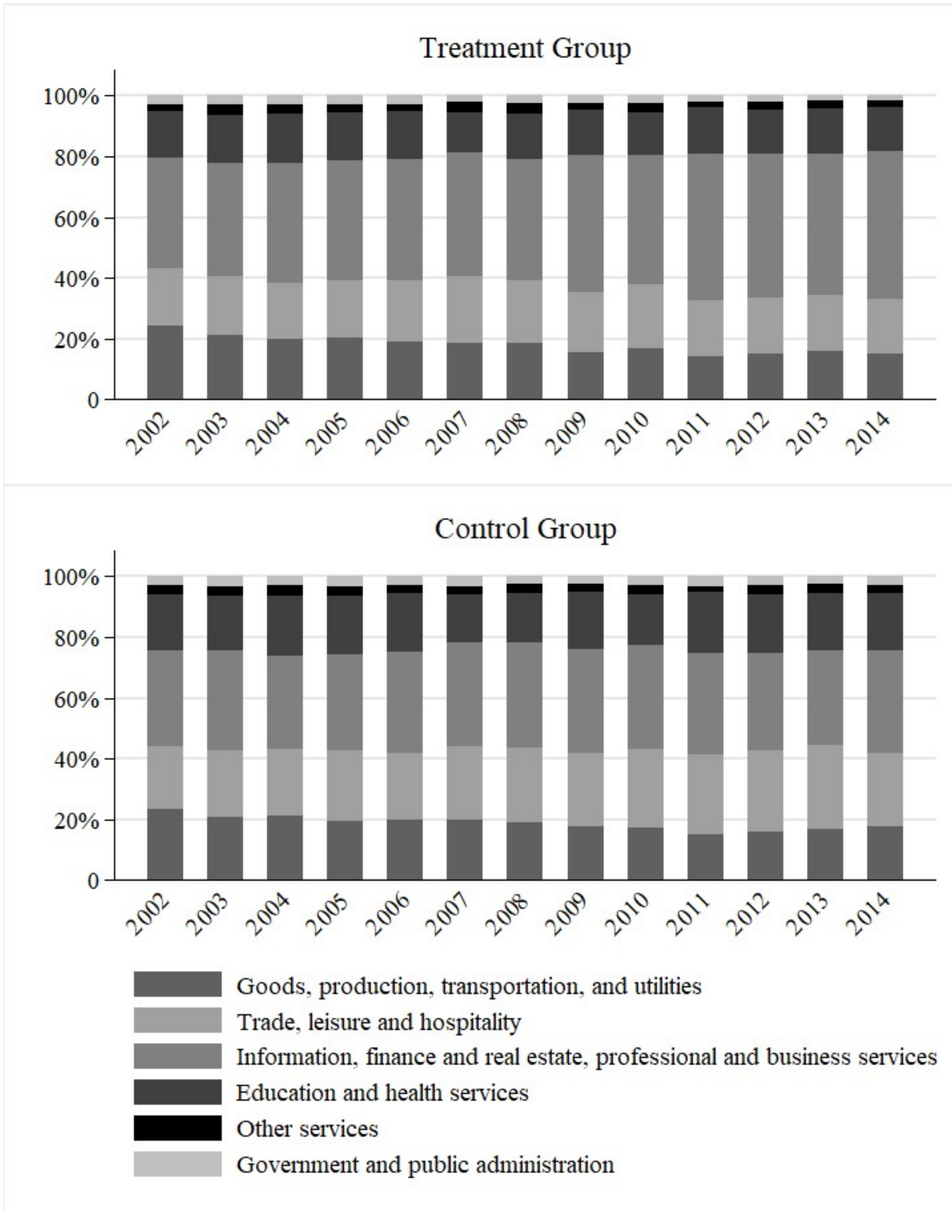

FIGURE 8: Share of jobs by industry supersectors for residence (RAC data)

To investigate the employment composition, I also study the earning categories in the treatment and the control groups for WAC and RAC separately. Figure 9 shows the share of jobs for the workplace per census block (WAC) by the wage category. More than 40% of the jobs in the treatment group were in high-wage category (greater than $3,333 per month) in 2002 and this share has been increased to almost 60% by the end of the study period in 2014. In the control group, more than half of the jobs were in the medium-wage categories (between $1,250 and $3,333 per month) in 2002 and it has been decreased gradually each year since then. After 2012, more than half of the workers have been in the high-wage category.

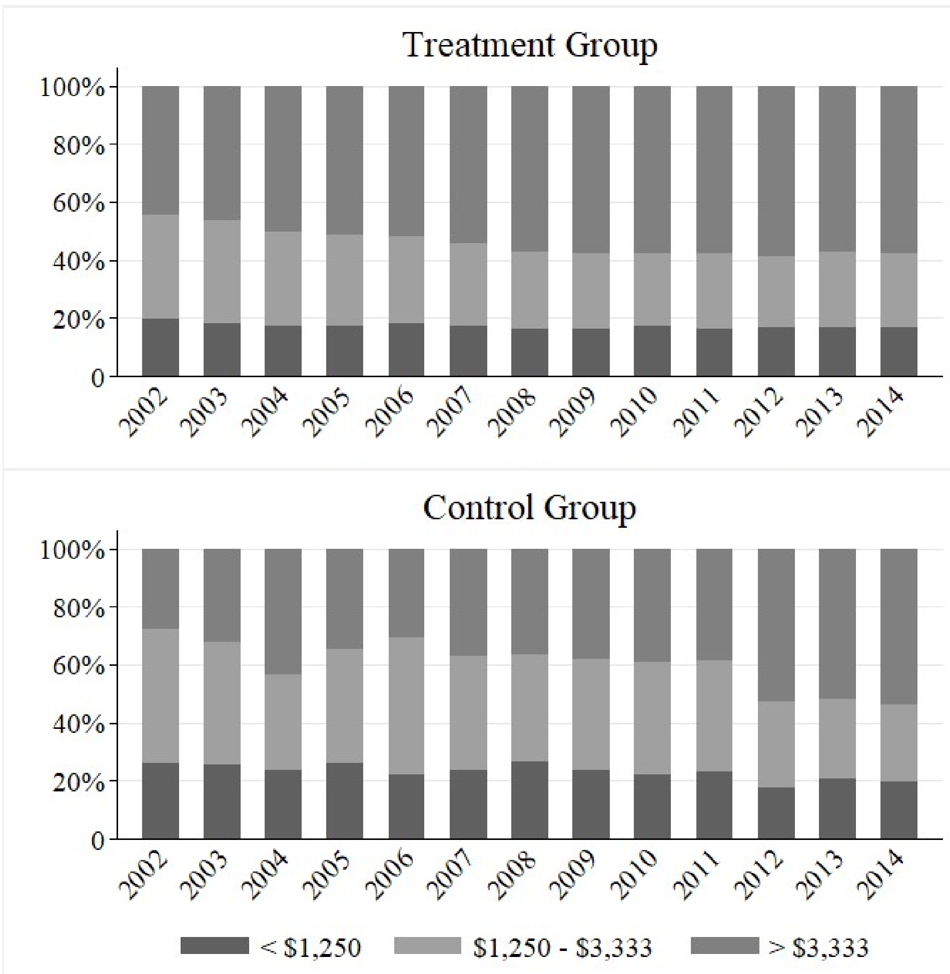

FIGURE 9: Share of jobs by wage category for workplace (WAC data)

Comparing the workplace to the place of residence, this increase in the higher-wage category was even more (Figure 10), starting with around 30% of residents being in the high-wage category in 2002 to almost 60% by 2014. This increase in high-wage residents suggests that this area sees changes in terms of economic condition of its residents. After the opening of the light rail, development of luxury condominiums and apartment complexes in downtown area and along the South Line rail, particularly in the South End and Dilworth neighborhoods have been boosted (Portillo 2017, Sealey 2018, Smoot and Lindstrom 2019). In the control group, the earnings composition of residents remains fairly stable over the time period.

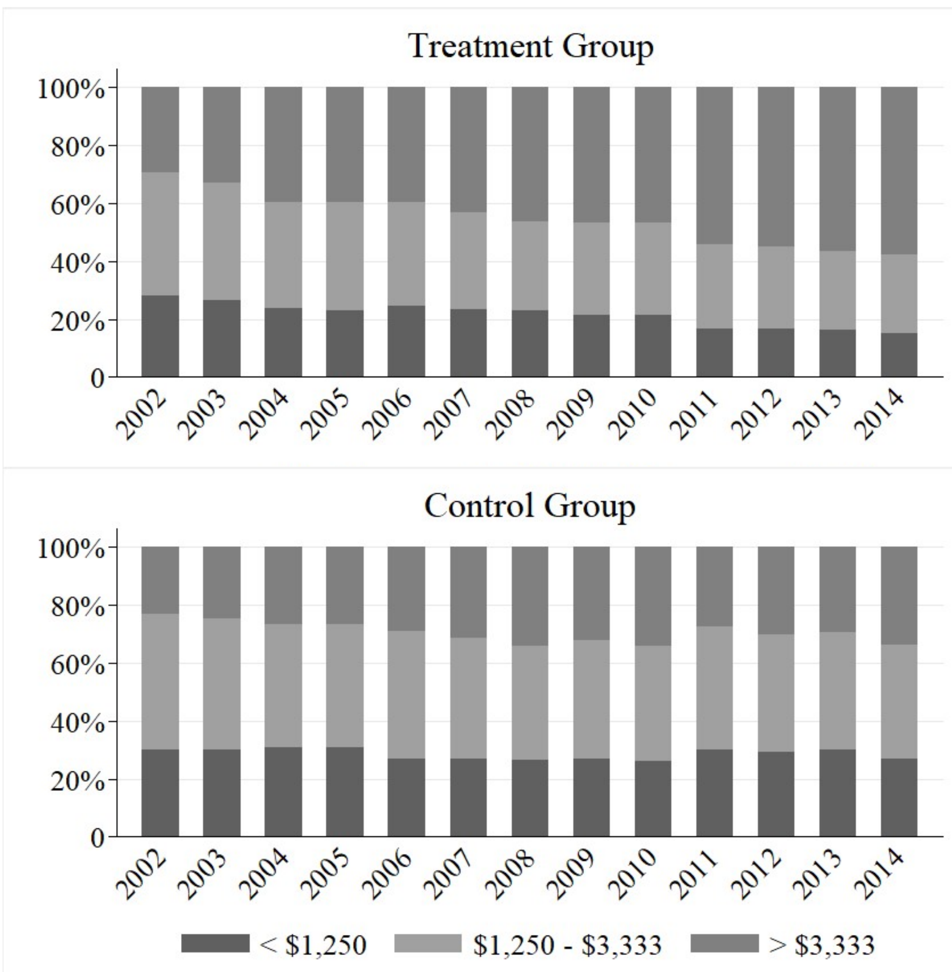

FIGURE 10: Share of jobs by wage category for residence (RAC data)

To examine the effect of the LRT investment on wage composition of the treatment and the control blocks, I estimate a similar model to the one in Equation (1) but with the share of workers/residents in the lowest- and highest-earning categories (workers with earnings $1250/month or less and workers with earnings greater than $3333/month), respectively, as the dependent variable. Table 5 presents the estimation results on the share of workers in the low- and the high-wage categories from WAC dataset and the share of residents in the low- and the high-wage categories from RAC dataset.

TABLE 5: DID estimation results of low- and high-wage categories for both WAC and RAC datasets

	WAC		**RAC**	
Variables	**Share of Low-Wage**	**Share of High-Wage**	**Share of Low-Wage**	**Share of High-Wage**
Treatment	-3.743877***	4.027562***	-3.011928**	4.972012***
Post-2007	-4.921748***	7.477666***	-4.78087***	6.483107***
Treatment * Post-2007	2.060518	-0.3453269	-0.8713026	5.246374***
Distance to City Center	0.3487675***	-0.583298***	0.1515562*	-0.6874881***
Recession	2.071173	-3.116426**	1.759151	-1.077631
Share of supersector 1	0.1164934	0.1680726	0.3534509	-0.5457831
Share of supersector 2	0.4653615***	-0.0515082	0.7536416**	-0.8065206**
Share of supersector 3	0.1239687	0.2988982**	0.3578269	-0.321518
Share of supersector 4	0.1940669*	0.0635825	0.4965449	-0.5606769
Share of supersector 5	0.4027218***	-0.0320456	0.7452278**	-0.836257**
Share of supersector 6	0.0183884	0.3066757**	0.4339755	-0.5632582
Intercept	6.912505	15.11518	-18.91664	85.90591**
N	3,437	3,437	2,240	2,240
AIC	30193.88	30535.58	19172.7	20063.98
Adjusted R^2	0.3077	0.2902	0.1639	0.2219
**Significant at $p < 0.05$, ***Significant at $p < 0.01$				

As expected, the results show that the treatment census blocks have pre-existing higher shares of the higher-wage workers' and residents' jobs over the control census blocks even before the introduction of the LRT, and at the same time have a lower share of the low-wage workers and residents. This can be explained by the fact that the treatment group contain blocks in the downtown area with a large number of jobs in information, finance, real estate, professional, business services, headquarters and also local government.

The coefficients of the Post-2007 variable for the different models suggest that both the control and the treatment blocks have experienced a significant increase in the share of high-wage jobs and a decrease in the share of low-wage jobs in the post-2007 period. Since this change is not just associated with the treatment neighborhoods, it may be an indication of the job composition change in the entire city after 2007 rather than the opening of the LRT.

The interaction term of the Post-2007 and the Treatment variables is only significant for the share of high-wage residents, suggesting that while both the treatment and the control blocks have experienced an increase in the share of higher income earners after 2007, this increase was significantly higher in the treatment group. This is an expected result given the increase in the share of high-wage residents shown in Figure 10.

The coefficient for the Distance to center city variable is significant and positive for the models with the share of low-wage jobs and residents, suggesting that there are fewer low-wage jobs and residents closer to the downtown. These findings are expected given the findings by Sanchez (1999) which suggest that lower-wage jobs are more dispersed in cities while high-skilled, higher-wage jobs tend to be concentrated in the city center (Sanchez 1999). The recession dummy has, as expected, a negative and significant effect on the share of high-wage jobs given the city of Charlotte's heavy dependence on the banking sector, which took a hard hit during the recession. Supersector 2, which includes trade, leisure, and hospitality, has an expected positive effect on the share of lower-wage jobs for both workers and residents, and a negative effect on the share of higher-wage jobs, since this supersector offers more low-wage jobs.

Supersector 3 and 6 have a significant positive impact on the share of high-wage jobs that can be explained by the fact that these supersectors consist of high-earning jobs in information, finance, real estate, professional services, business services, and governments (note that high-wage jobs mean earning greater than $3,333 per month).

Table 6 shows the results of the difference-in-difference estimation for the share of higher-level jobs and retail jobs. Higher-level jobs include Information, Finance and Insurance, Real Estate and Rental and Leasing, Professional, Scientific, and Technical Services, Management of Companies and Enterprises.

TABLE 6: DID estimation results of higher lever and retail jobs for both WAC and RAC datasets

Variables	WAC Share of Higher-Level Jobs	 Share of Retail Jobs	RAC Share of Higher-Level Jobs	 Share of Retail Jobs
Treatment	4.712673***	6.001747***	7.178201***	-1.95732**
Post-2007	2.418151	0.20249	1.910901*	0.574203
Treatment * Post-2007	-2.09405	-2.20752	-0.13117	0.056736
Distance to City Center	-1.33236***	1.901234***	-0.72839***	0.209273***
Recession	1.264909	0.25175	-0.94169	1.968481*
Intercept	30.82029***	2.043168**	26.05717***	9.672616***
N	3,437	3,437	2,240	2,240
AIC	33746.31	31295.45	19434.46	17884.83
Adjusted R^2	0.0373	0.1036	0.0727	0.0120
Note: Significant at the ***1%, **5%, *10% significant level.				

The results show that, with the exception of the share of retail jobs in RAC, the treatment census blocks have pre-existing higher shares of retail and higher-level jobs over the control census blocks even before the introduction of the LRT in WAC and RAC. The only other significant variable is distance, which shows the share of higher-level jobs decreases by going further away from the center city, and the share of retail jobs increases by going further away. As noted earlier, this is likely because banking and financial services jobs are located in the center city of Charlotte.

6.2: CONNECTING PEOPLE WITH JOBS: LIGHT RAIL'S IMPACT ON COMMUTING PATTERNS

In this section of my dissertation, I study the effect of light rail transit investments on computing patterns in adjacent neighborhoods.

Table 7 shows the estimation results of Equation (1) described in the previous section. In Model 1, Equation (1) is estimated for the years before the LRT opened (2002-2006) with 2002 as the reference year. In Model 2, the same equation is estimated for the years after the LRT opened (2007-2014) with 2007 as the reference year. Finally, in Model 3, Equation (1) is estimated with year fixed effects for the entire study period, using 2007 as the reference year. Across all three models, all the control variables have the expected signs.

The results from Model 1 and 2 show that both low-wage and medium-wage workers are less likely to commute to LRT blocks for work than high-wage workers before and after opening of the light rail, suggesting a lack of jobs corresponding to these wage categories in the LRT areas. This makes sense, particularly in the downtown area, given the industrial make-up of the area, which contains more high-wage office jobs in the city's many headquarters (mostly in banking and finance). This is further supported by the estimated coefficients for share of in-commuters in industry category 1 (Goods Producing industries) and industry category 2 (Trade, Transportation, and Utilities) which suggest that workers are less likely to commute to LRT blocks for work in these industries compared to jobs in industry category 3 (All Other Services). This industry category includes finance, insurance, banking, managerial, information, and professional, scientific jobs. Looking at the coefficients in Model 2, I can see that in the time period after the opening of the light rail, the probability of high-wage workers to commute to the LRT blocks is even higher than before, compared to the coefficients in Model 1.

TABLE 7: Regression Results

Variables	Model 1	Model 2	Model 3
Percent Low-wage workers	-0.0124802**	-0.0185564**	-0.01626**
Percent Medium-wage workers	-0.0166343**	-0.0248642**	-0.0216586**
Percent Industry 1 workers	-0.0175191**	-0.0148951**	-0.0157034**
Percent Industry 2 workers	-0.0129182**	-0.0121907**	-0.0125118**
Origin is a light rail block	9.868841**	12.19595**	11.47582**
Commute distance (miles)	-0.0389781**	-0.046274**	-0.0437045**
Year Fixed Effect			
2002	Ref.	-	-0.0012
2003	0.3949501**	-	0.4000482**
2004	0.1692128**	-	0.1382587*
2005	0.0212625	-	-0.0033882
2006	-0.1504029*	-	-0.1889864**
2007	-	Ref.	Ref.
2008	-	0.391548**	0.3977605**
2009	-	0.5035751**	0.5059257**
2010	-	0.1442457**	0.1487455**
2011	-	0.9237384**	0.9364566**
2012	-	-0.8904508**	-0.8719138**
2013	-	-0.5617469**	-0.5486318**
2014	-	-0.920698**	-0.9127804**
Intercept	13.15319**	13.83183**	13.59335**
N	233814	393,003	626,817
Adj R-squared	0.0818	0.1435	0.1183
F	2083.62	5067.06	4674.33
*Significant at p < 0.05			
**Significant at p < 0.01			

The coefficient of the Commute Distance variable shows a consistent relationship through the different models. It suggests that workers in the LRT blocks are more likely to come from neighborhoods closer to these blocks. As the magnitude of the coefficient for this variable is relatively stable across the models, we cannot infer the changes over time in the workers preference to live closer to where they work. However, the magnitude of the coefficient for the origin being another LRT block is greater in the post-opening model. It is 12.2 in the post-period compared to 9.87 in the pre-period, which is indicative of a greater share of workers that both live and work in the LRT neighborhoods after the opening of the light rail. We can also see this in Table 8, which breaks down the number of commuters between origin-destination, year, and wage category. The total rows in table 8 for 2002 and 2014 show that the number of workers who both live and work in the LRT neighborhoods more than doubled while the number of workers who work in the LRT neighborhoods but live elsewhere in the county actually reduced in number. Table 8 also shows that, while the share of both high-wage residents and high-wage workers in the light rail blocks have increased, the share of low- and medium-wage residents and low- and medium-wage workers in the light rail blocks have decreased considerably.

TABLE 8: Share of Low-, Medium-, and High-Wage Residents and Workers in LRT Blocks in 2002 and 2014

		(A) Resides in LRT blocks, but works outside of LRT blocks	(B) Works in LRT blocks, but resides outside of LRT blocks	(C) Works and resides in LRT blocks
2002	Low-wage	440 (29.89%)	6,601 (18.84%)	58 (19.21%)
	Middle-wa	647 (43.95%)	12,336 (35.21%)	103 (34.11%)
	High-wage	385 (26.15%)	16,102 (45.95%)	141 (46.69%)
	Total	1,472	35,039	302

2014	Low-wage	319 (14.84%)	5,933 (17.11%)	78 (10.64%)
	Middle-wage	634 (29.50%)	8,482 (24.46%)	129 (17.60%)
	High-wage	1,196 (55.65%)	20,260 (58.43%)	526 (71.76%)
	Total	2,149	34,675	733

As noted earlier, the high presence of high-wage workers is likely due to the industrial make-up of the areas adjacent to the light rail. Since the OD data file from LODES only considers three very broad industry categories, I use the WAC and RAC data files to calculate the share of residents as well as workers in different industries. The WAC and RAC data files reveal more detailed information about the industries in each block. Modifying NAICS Super Sectors from Current Employment Statistics (CES) program by the Bureau of Labor Statistics (BLS), I grouped some industries together. These modified Super Sectors include:

Super Sector 1: Goods, production, transportation, and utilities

Super Sector 2: Trade, leisure and hospitality

Super Sector 3: Information, finance and real state, professional and business services

Super Sector 4: Education and health services

Super Sector 5: Other services

Super Sector 6: Government and public administration

Figures 11 and 12 show that Super Sector 3, which includes information, finance and real estate, professional and business services, is the only Super Sector that has a notable increase in its share of workers that both reside (36.3% to 48.6%) and work in the light rail blocks (62.5% to 69.1%) between 2002 and 2014. The large (and growing) share of jobs in this sector in the LRT neighborhoods and the growing presence of workers from industry residing in the LRT neighborhoods, could suggest that there is a better spatial match between residents and jobs along the light rail line. The increase in the percentage of workers in Super Sector 3, which is often associated with higher-wage jobs, can be related back to the regression results in Table 7 that indicate an increase in the share of higher-wage jobs. These results are expected as the light rail stations in the downtown area of Charlotte are surrounded by a high concentration of Super Sector 3 establishments such as the Bank of America Headquarter, the Wells Fargo Securities Headquarter and other financial service offices.

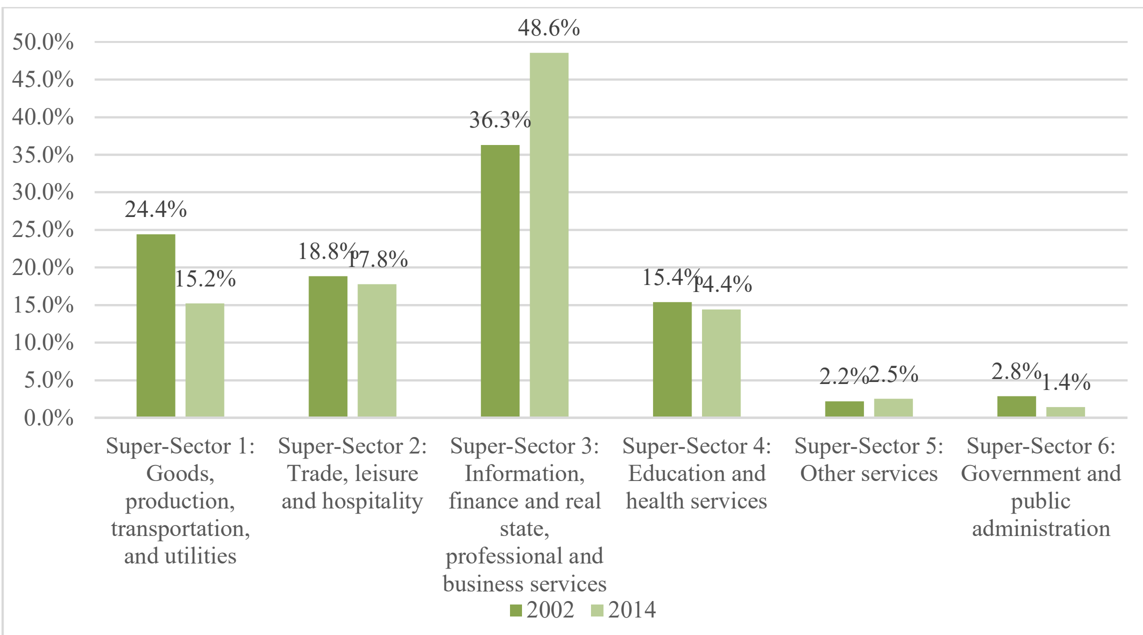

FIGURE 11: Percent in different industry Super Sectors for those who reside in LRT blocks in 2002 and 2014

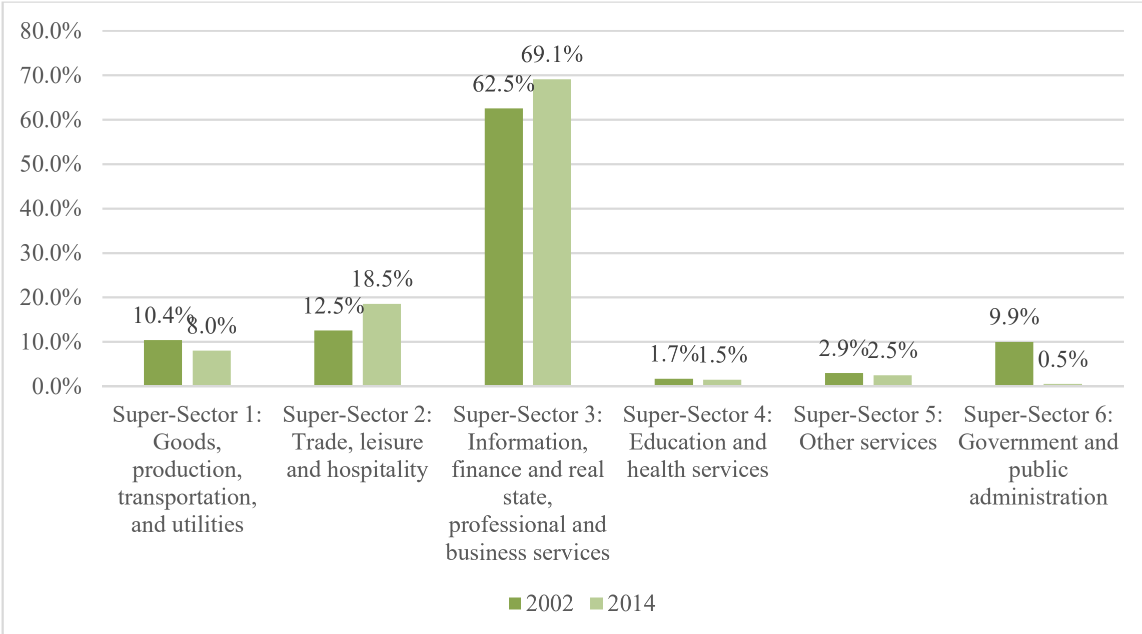

FIGURE 12: Percent in different industry Super Sectors for those who work in LRT blocks in 2002 and 2014

Concerning the results regarding the distance to work in the light rail blocks and the large share of higher-wage workers in the light rail blocks, the number of high-wage workers who reside in the light rail blocks and have a shorter commuting distance is significantly more than the medium- and low-wage workers who have short commuting distance (Figure 13). In other words, commuting distance is a lot shorter for the high-wage workers who reside in the light rail blocks than the medium- and low-wage workers, and commuting distance is on average shorter for the medium-wage workers than the low-wage workers in both 2002 and 2014. It is an interesting finding since the literature on the housing-transportation trade-off suggests that higher income earners value space and quality of housing more than commuting time, and hence choose to live farther from their work location in the CBD (Alonso 1964, Muth 1969, Mills 1972). However, the findings here suggest that higher income earners value time more and choose to live closer to their job location and have a shorter commute. There are two potential explanations to these findings. The idea that people value time differently based on income has a long history in the literature (Higgins et al. 2018). Therefore, one explanation to the changes observed is that higher-wage workers value time more than lower-wage workers do due to the higher opportunity costs of commuting and consequently they move to be closer to their job location. Alternatively, higher-wage workers may be attracted to the light rail neighborhoods through improvements in housing quality brought along by the development of TOD districts with new, relatively more expensive housing units and an increase in neighborhood amenities such as walkability and new restaurants and all other urban amenities.

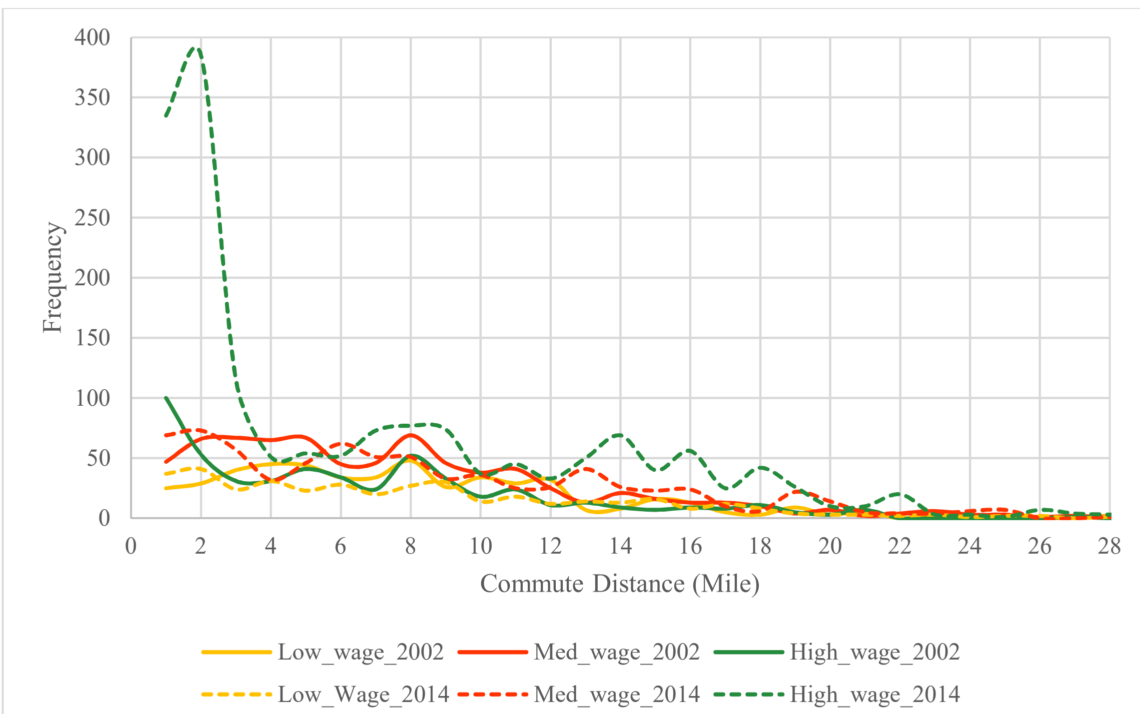

FIGURE 13: Distance for low-, medium-, and high-wage workers who reside in light rail blocks and work in Mecklenburg County (2002 – 2014)

However, if we take a closer look at those that work (but not necessarily live) in the light rail neighborhoods, there are still significant amounts of the high-wage workers that commute from greater distances. Still, the share of high-wage workers commuting shorter distances has increased significantly compared to the other wage groups (Figure 14).

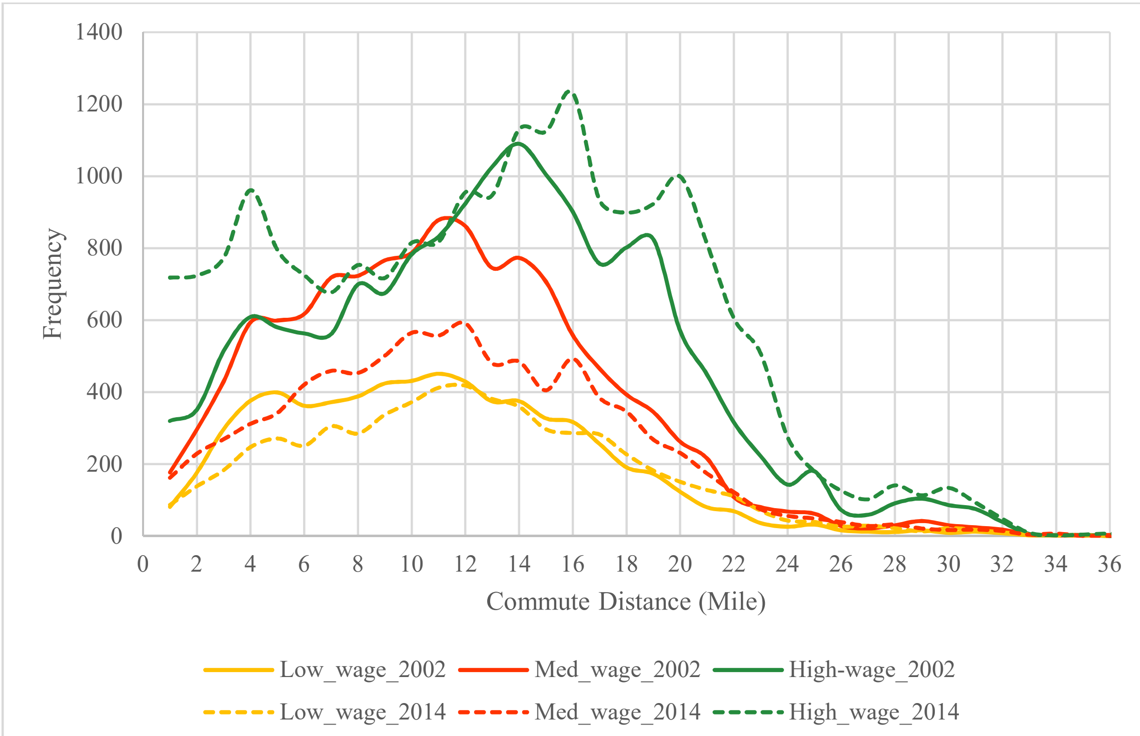

FIGURE 14: Distance for low-, medium-, and high-wage workers who work in light rail blocks and reside in Mecklenburg County in 2002 and 2014

In general, commuting distance tend to be shorter for those who reside in the LRT blocks and work anywhere in Mecklenburg County than those who work in the LRT blocks and reside anywhere in Mecklenburg County (Table 9). That is probably because most of the people who reside in and around the light rail area also work there as indicated by the results in Tables 7 and 8. For those people who work in the light rail blocks in 2002 and 2014 (regardless of wage category), the commuting distance increased a bit but it is not very considerable for either of the wage categories (Table 9). On average, the commuting distance for those who work in the light rail blocks is twice of those who reside in the light rail blocks. For example, in both 2002 and 2014, the commuting distance for the high-wage workers who reside in the light rail blocks is almost half of that experienced by those who work in the light rail blocks (Table 9).

Average commuting distance does not change considerably after the opening of the light rail, while I assumed that it should have some impacts on the average commuting distance (Table 9). For both those who reside in the LRT blocks and work there for all three wage categories, the average commuting distance does not have any considerable change.

TABLE 9: Average commuting distance (in miles)

		Low wage	**Medium wage**	**High wage**
Reside in LRT blocks	2002	4.78	4.66	3.87
	2014	4.76	5.12	4.09
Work in LRT blocks	2002	6.48	6.77	7.83
	2014	7.22	7.08	7.85

6.2.1 COMMUTING MODE SPLIT

This study used the LODES census block estimates of commuting flows. However, one of the limitations of the LODES data is that it does not include mode of transportation data. The only available data for mode split is offered by American Community Survey (ACS) from U.S. Census Bureau. However, ACS data on mode choice (Data for 2000 collected from Means of Transportation to Work for Workers 16 Years and Over and Data for 2014 collected from Commuting Characteristics by Sex) is published at the census tract level and it is very noisy (U.S. Census Bureau, 2018b). While it is noisy (i.e., has large margins of error), it is one of the few data sources available at disaggregate geographic units containing estimates on mode split. Therefore, in order to get a sense of whether there has been changes in mode split between the opening of the light rail and after, we perform a brief descriptive analysis of this data and compare it to estimates for the nation.

In the United States in 2000, the share of workers of 16 years old and over who went to work by car, truck, or van was 87.88%, by public transit was 4.73%, and worked at home was 3.26% (U.S. Census Bureau, 2019c). In 2014, the mode split was very similar to 2000. The share of workers who went to work by car, truck, or van was 86.0%, by public transit was 5.1%, and worked at home was 4.4% (U.S. Census Bureau, 2019d). Comparing Charlotte to the national trend of mode split, we see that Charlotte follows a very similar trend to the nation in terms of mode split. Means of transportation in Mecklenburg County in 2000 and 2014 are shown in Figure 15. In 2000, the share of commutes by car, truck, and van was 4% more in Mecklenburg County compared to the nation, however, in 2014, the share of commutes by car, truck, and van in Mecklenburg County were closer to the nation-wide percentage (86.0% in the US and 87.30% in Mecklenburg County).

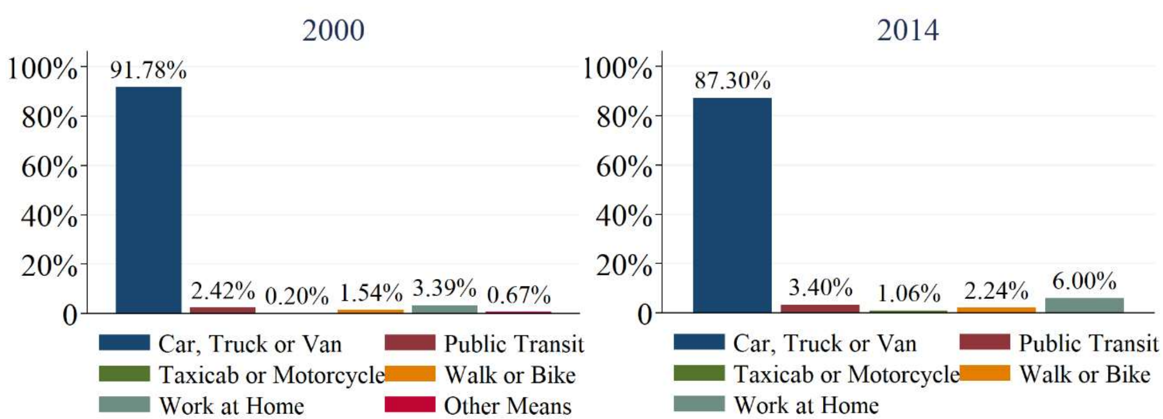

FIGURE 15: Means of transportation in Mecklenburg County (%)

Data source: Data for 2000 from Means of Transportation to Work for Workers 16 Years and over. Data for 2014 from Commuting Characteristics by Sex. American Community Survey, U.S. Census Bureau. In data for 2000, there was a category for “Other Means” that data in 2014 does not have.

In short, despite the recent investments in the light rail transit in Charlotte, the city remains auto-centric with an overwhelming share of commutes being made by car. Figure 15 shows the mode split in Mecklenburg County in 2000 and 2014, where we can see seven years after opening of the Charlotte's first light rail line. Commutes by public transit had only increased by one percentage point and commutes by car, truck, and van had only decreased by four percentage points.

6.2.2 COMMUTING TIME

LODES data also does not include travel time data. The only available data for travel time is offered by American Community Survey (ACS) from U.S. Census Bureau and 2006 is the earliest date commuting time data is available at the county level. This data also is very noisy and has large margins of error. However, this is the only data available for travel time in county level. Therefore, in order to get a sense of whether there have been changes in travel time between the pre- and post-opening of the light rail, we perform a brief descriptive analysis of this data and compare it to estimates for the nation.

In the United States, average commute time has not been changed a lot from 2006 to 2014 (Figure 17). In general, Mecklenburg County has higher share of longer commute time of 20 minutes to 44 minutes than the United States. However, its general trend is very similar to the nation. Overall, the distribution of commute times in Mecklenburg County in 2006 and 2014 look similar. There is just 1.2% decrease in the commute of less than five minutes and 2.3% decrease in the 20-24 minutes of commute. There is 2% increase in 25-29 minutes of commute, 1.6% increase in 30-34 minutes. Therefore, we see a slight increase in commute time in general however, given the margins of error associated with the data, these changes may not be significant.

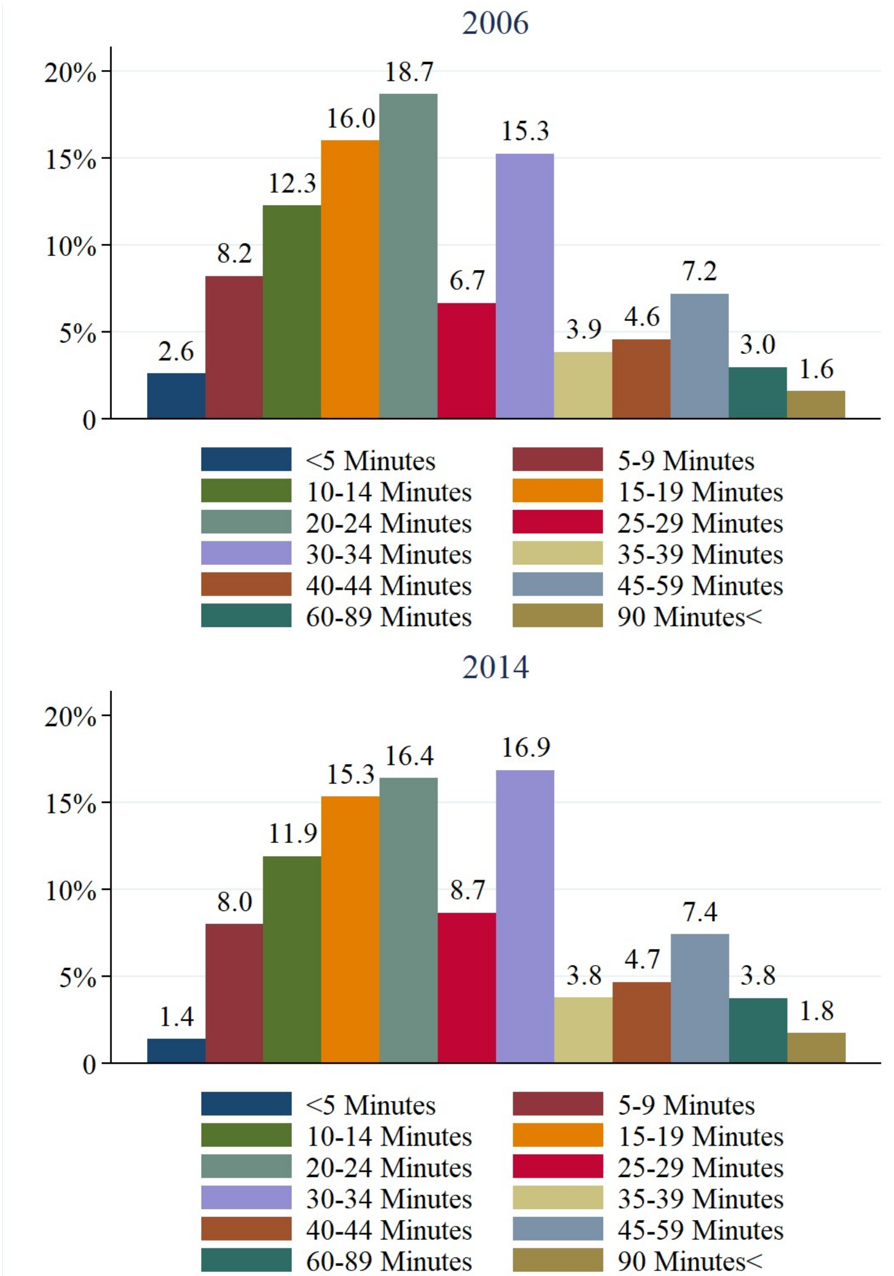

FIGURE 16: Travel time to work in Mecklenburg County (%)

Data source: Data for 2006 Travel Time to Work, Universe: Workers 16 years and over who did not work at home. Data for 2014 from Travel Time to Work, Universe: Workers 16 years and over who did not work at home. American Community Survey, 1-year estimates U.S. Census Bureau.

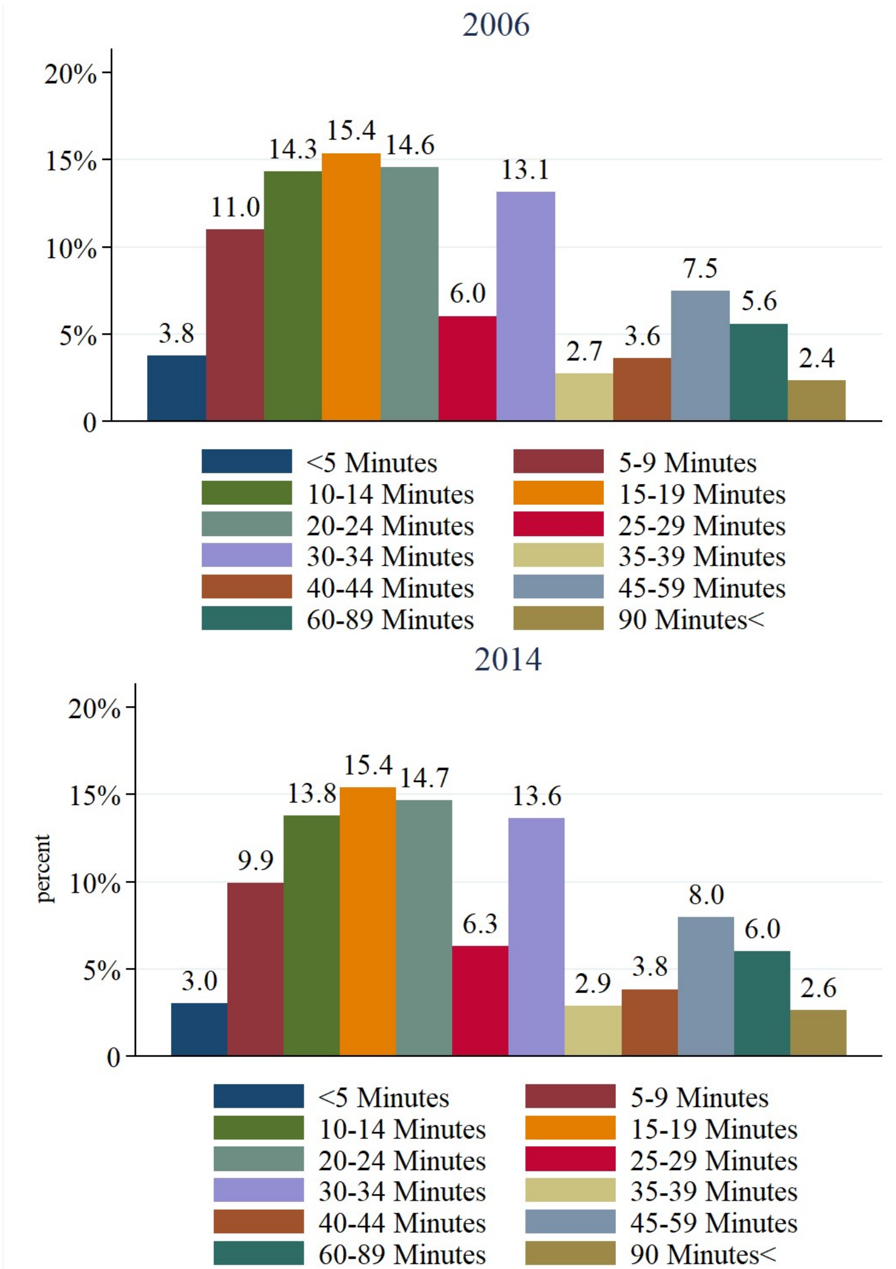

FIGURE 17: Travel time to work in the United States (%)

CHAPTER 7: DISCUSION AND CONCLUSIONS

The first part of this research investigated the effect of light rail investment on industrial makeup and wage composition of both workers and residents in Charlotte, NC. The results show that, in general, the treatment group had a prior advantage in number of jobs even before the introduction of the light rail compared to the control group. However, there is no significant increase in the number of jobs in the treatment group after the introduction of the light rail. After the opening the South Line in 2007, both the control and the treatment blocks experienced a significant increase in the share of high-wage jobs. The largest increase of jobs in both the treatment and the control blocks was attributed to supersector 6 (Government and public administration) followed by 3 (Information, finance and real state, professional and business services) and 4 (Education and health services). In other words, LRT has not specifically increased employment in the neighborhoods in the vicinity of the light rail stations relative to similar neighborhoods without light rail stations, but all of the neighborhoods in the treatment and the control groups have seen these changes. For workers residing in these neighborhoods, there is a greater concentration of residents further from the city center in the control and the treatment group combined.

In terms of the industrial and wage composition of the treatment and the control groups, there are noticeable differences. Almost 70% of treatment blocks consist of jobs in information, finance, real estate, professional, and business services (supersector 3), which also associated with higher-earning jobs and only 30% of the jobs are in the other industries. In the control group, supersector 3 (higher-earning jobs) covers just 20% of the jobs and it declines as time passes, while government and public administration jobs jump in 2012 to cover almost 50% of the jobs in the control group. Share of the higher-wage workers in the treatment group has increased after the introduction of the light rail from 40% in 2002 to 60% in 2014. In the control group, share of the medium-wage workers decreased from 50% in 2002 to 30% in 2014 and share of the high-wage workers has increased from 25% in 2002 to 50% in 2014.

Workers residing in the treatment group also have higher share in higher-wage jobs in supersector 3 than the control group. Increase in the higher-wage residents in the treatment group is even higher. It has been increased from around 30% in 2002 to almost 60% in 2014. This increase in high-wage residents suggests that this area sees changes in terms of economic condition of its residents. We know that after the introduction of the light rail, there has been an increase in the development of luxury condominiums and apartment complexes in downtown area and along the South Line rail, particularly in the South End and Dilworth neighborhoods (Portillo 2017, Sealey 2018, Smoot and Lindstrom 2019). In the control group, the earnings composition of residents remains fairly stable over the time period.

After 2007, both of the control and the treatment blocks experienced a significant increase in the share of high-wage jobs and a decrease in the share of low-wage jobs. This change is not just associated with the treatment blocks, and it may indicate a change in job composition of the entire city rather than the opening of the light rail.

In my theoretical framework, I expected to see changes in industrial composition and land use of the treatment group after the introduction of the light rail, from more land intensive businesses to less land intensive businesses, where the movement of people is important to the firms. This change occurred in both treatment and control groups, and not just in the treatment group. Since this change is not just associated with the treatment neighborhoods, it may indicate a change in industrial and wage composition and number of employment in the entire city after 2007 rather than in the neighborhoods affected by the opening of the LRT.

While the goal of transit investment is to connect people to employment areas, particularly transit-dependent people who are usually in the lower-income category, the results of this study show the opposite. Generally, the results show that the light rail was positioned in areas with a pre-existing higher share of workers and residents in higher-wage and higher-skilled industries. The share of these types of jobs have increased in the light rail adjacent neighborhoods across the entire study period. Similarly, more higher-skilled and higher-wage workers choose to live in these neighborhoods. While this trend started before the opening of the light rail, there was a significant increase in the share of higher-wage workers who choose to reside in these neighborhoods after the opening of the light rail and its associated developments of high-end condominiums and apartment complexes along the rail line. Hence, the light rail appears to connect higher-wage neighborhoods to areas with significant shares of higher-wage jobs while low-wage workers in light rail adjacent neighborhoods have not seen a significant change in the spatial separation between their work place and place of residence after the opening of the light rail. With regard to the theoretical framework set out in this dissertation, I expected to see either this result of increasing office jobs such as finance, information, real estate, and professional services that typically associated with higher-wage workers, or an increase of retail and service firms that typically associated with lower-paying occupations and consequently an increase in demand by the lower-wage workers. In our treatment group, clearly, there is a combination of both office and retail/service jobs. However, as stated earlier, the outcome is more favorable towards higher-wage workers because of the development of high-end condominiums and high rents. These findings conflict with the goals of increasing accessibility for the most transit-dependent population. Particularly in a city where upward mobility and income segregation has been a topic of discussion since the publication of a report ranking Charlotte at the bottom in terms of economic mobility out of the 50 largest U.S. cities (Leading on Opportunity 2019).

Regarding future research, there is an obvious need for more analyses on the effect of light rail investment on the spatial (re)distribution of industrial and wage composition of employment. Future research can benefit from the inclusion of other control variables that may have an impact on the redistribution of jobs and residents. These control variables could be any incentives that may affect firms' location decision-making such as tax breaks offered by the local government or land-use zoning, and residents' location decision-making such as their race and gender.

In the second part, this research investigates the relationship between the investment in the light rail transit and its possible effect on commuting patterns in neighborhoods adjacent to the light rail in a case study on Charlotte, NC. It investigates changes in commuting patterns experienced by low-, medium-, and high-wage workers. The results of this analysis suggest that the light rail investments reduced the average commuting times for the higher-wage workers and potentially reduced the spatial mismatch between the higher-wage jobs and resident locations. The tendencies for the light rail transit investments to be focused around neighborhoods experiencing socioeconomic ascent has been noted in the previous literature (see for example Nilsson and Delmelle 2018). Without reliable mode split data at small geographic units (American Community Survey tends to be associated with large errors at the neighborhood level), it is difficult to infer whether the higher-income earners actually commute by rail to work or whether they simply move to the light rail neighborhoods but still commute by car and/or work in areas not adjacent to the light rail. My analysis suggests that the higher-wage workers are attracted to reside in the light rail neighborhoods but may not necessarily work there or in other LRT-adjacent neighborhoods even though there is a large share of higher-wage jobs in these areas to begin with.

Given that lower-wage workers are likely more dependent on the public transit than the higher income earners, there is an employment and social justice argument to be made regarding whether light rail transit should better aim at connecting the lower-wage workers with the low-wage jobs. However, as noted in the literature review, the lower-wage jobs tend to be more decentralized (Hu and Schneider, 2017) and the fixed rail transit (which often operates in a spoke-and-hub rather than in a point-to-point network) may not be the optional solution. Hence, the findings from this study lend support to the hypothesis raised in the previous literature regarding the light rail transit investments being placed in neighborhoods that have, or are in the process of undergoing, some kind of socioeconomic ascent (Canales et al 2019).

When the fixed rail transit investment does not increase access to areas of employment for the low- and medium-wage workers, increasing economic development is often cited as the main reason of the rail transit investments. However, given the cost of implementing rail transit ($521.9 million in the case of the LYNX Blue Line (Hartgen

2008)), the question is whether there are more cost-effective ways of boosting economic development and revitalizing urban areas previously faced by disinvestment. Thus, the fact is that connecting the high-wage workers with the high-wage jobs can improve the spatial mismatch for the higher-wage workers and can have other positive impact such as decreasing congestion or emission, however, it does not appear that there has been a shift in mode choice among Charlotte residents given available mode share statistics.

The results regarding reduced commuting distance for the higher-wage workers suggests that there might be a shift where the higher income earners appear to place more value on time than suggested by early scholars and/or increased quality of housing in the neighborhoods near the CBD (Alonso 1964, Muth 1969, Mills 1972) and it is more in line with the great inversion hypothesis by Ehrenhalt (2012) who suggest that higher-middle-class white childless professionals, or affluent retirees move to be in proximity of downtown areas, which gradually becomes safer, to have shorter commutes and use the livability of the city centers. The increasing commuting distance for the low- and medium-wage workers during the study time period points to a larger trend which is often referred to as the "suburbanization of poverty" or the great inversion hypothesis that predicts middle-class African-American and immigrants are attracted to the safety, good schools, good housing, and good jobs in the suburbs. This trend has been apparent in Charlotte, where the public discourse suggests that the lower income residents are moving further and further out from the city core (Badger 2013). Such trends pose new challenges for transportation planners and raise questions regarding how to serve an increasingly dispersed public dependent population. The City of Charlotte has started to take steps towards addressing this problem by collaborating with Uber and Lyft to solve the last mile problem to their rail transit stations (CATS 2018). It points to the importance of studying housing and transportation together as suggested by Cortright (2017) who emphasizes on affordable living (which includes both transportation and housing costs together) rather than the affordable housing.

Future research that examines other cities with varying levels of rail transit services can provide further evidence about the role of rail transit on commuting patterns. Charlotte is, like many other US cities, a sprawling city with lots of suburbs and highly segregated neighborhoods (Hanchett 1998). However, studying other cities can provide more context and improve our understanding of the effect of the light rail transit investment or in general, the public transit investment on commuting patterns for different wage categories. In addition, based on data availability, future research can control for other potential significant variables including mode of transportation.

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