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Estimating the value of a new transit option

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ABSTRACT

The research presented here argues that identifying the impacts of rail transit on property values is not possible without estimates of both price gradients to transit stations as well as overall property value trends in transit neighborhoods. The latter may highlight a number of secondary impacts of rail transit on nuisance elements such as crime and parking as well as targeted public and private investment along rail-transit corridors. In order to estimate neighborhood property values, one must establish relevant control neighborhoods. In the case of Charlotte, North Carolina, the public planning and funding process provides information on proposed light rail-transit (LRT) corridors that were ultimately not selected as the first alignment in Charlotte's light rail transit system in 2000. Estimation incorporates a difference-in-difference estimator across a range of hedonic models. Preferred estimates highlight that LRT provides a neighborhood impact of 4.0% for single-family properties and 11.3% for condominiums sold within 1 mile of LRT stations. No neighborhood impacts are realized for commercial properties and estimated price gradients provide insignificant impacts across a number of models. Results suggest that LRT investment may be used more as an economic development tool for specific neighborhoods rather than a transportation amenity in cities like Charlotte, which contain sparser development patterns.

1. Introduction

The popularity of light rail transit is puzzling to most economists. All U.S. light rail transit systems require substantial public funding of their initial construction and subsidized operations. For most commuters, light rail transit (LRT) offers limited time savings over bus transit and is inflexible in its geographic scope of service. Despite these shortcomings and high costs, we have seen a number of cities recently invest in LRT. Seventeen of the existing 24 light rail transit systems[1] in the U.S. began operations since 1980. This investment in light rail transit is often linked to the 'smart growth' movement[2] and escalating congestion costs throughout a number of high growth, mid-sized cities. Urban planners tout the benefits of higher LRT ridership than comparable bus transit due to greater utility in terms of commuter experiences. Evaluating the benefit of this populous support for LRT is of policy importance as local as well as the federal government continue to invest billions of dollars in LRT infrastructure.[3]

In order to better guide public decisions, scholars estimate LRT benefits based on the premise that close proximity to LRT access points (stations) should provide an amenity value to riders.[4] Therefore, local land markets should account for this benefit through land rents. Estimates of capitalization often involve regressing residential property values on a measure of proximity to a LRT station while controlling for confounding neighborhood attributes. Negative housing price gradients indicate a positive impact of rail transit. Using a meta-analysis across the literature, Debrezion et al. (2007) conclude a median property value increase of 26% as one moves 820 ft closer to a rail transit station.

The research presented here argues that estimated price gradients are insufficient to identify the impacts of rail transit and that estimates of both a price gradient as well as neighborhood property values are required to disentangle the access amenity from the neighborhood effects of rail transit. As discussed by Bowes and Ihlanfeldt (2001), the literature has identified four main outcomes, both positive and negative, that may influence the capitalized value of rail transit. The first involves access to a transportation alternative for commuters and

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[1] Listed by highest to lowest ridership, the 24 systems are Boston, San Francisco, Los Angeles, Portland, San Diego, Philadelphia, Dallas, Denver, Newark, Sacramento, St. Louis, Salt Lake City, Houston, Jersey City, Baltimore, Phoenix, San Jose, Minneapolis, Pittsburgh, Buffalo, Charlotte, Newark, Seattle and Cleveland (American Public Transportation Association, 2009). This excludes heavy rail systems such as Chicago, New York City, San Francisco and Washington DC as well as heavy commuter rail to suburban cities.

[2] See Handy (2005) for a discussion of LRT in the context of 'smart growth' based urban developments.

[3] Kahn (2007) states that over $25 billion were spent on the construction of new rail transit lines between 1970 and 2000.

[4] See Hess and Almeida (2007) and Debrezion et al. (2007) for recent reviews of this literature. There are over 100 papers that provide an estimate of the impacts of heavy or light rail transit.

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this is hypothesized to be directly related to the distance between residential properties and rail transit stations. The second factor is the positive effect of rail transit stations on commercial development. In order to serve transit riders, retail establishments may increase around rail transit stations and thus improve commercial services for the surrounding neighborhood. The remaining two factors relate to nuisances from the operation of rail transit and associated parking congestion from riders as well as the greater opportunity for crime with improved access to LRT neighborhoods.

Additionally, we argue that the neighborhood surrounding rail transit stations are often part of a larger effort by a city to encourage growth in the value and intensity of land-use in these corridors.[5] Rail transit may signal a focus of future investment dollars by the city as well as private landowners for neighborhoods served by rail transit.[6] This targeted development could affect commercial services for the neighborhood as well as encourage the development of new condominiums and single family homes around rail transit stations.[7]

This paper incorporates residential and commercial property value hedonics to determine the value of both accesses to LRT stations as well as overall neighborhood change. We apply these hedonic estimators to Charlotte, NC which began operations of LRT in November 2007 after a detailed planning process selected a single alignment (South Line) over two proposed corridors in September 2000. This research uses the timing of LRT announcement and corridors considered, but ultimately not selected for LRT, to identify control corridors for a difference-in-difference estimator. The entire population of single-family properties, multi-family ownership units (condominiums) and commercial properties sold since 1994 that are proximate to the actual or proposed LRT corridors are used in hedonic estimators. Results indicate a positive neighborhood effect across most empirical models with our preferred estimate indicating positive capitalization of 4.0% for single-family properties, 11.3%for condominiums and no capitalization for commercial properties. Stronger effects exist for condominiums and properties in more urban Walk-N-Ride LRT neighborhoods. Additionally, these positive impacts are present across both hedonic and repeat sales estimators as well as with the creation of alternative control groups using propensity score matching. Estimates of the price gradient effect, based on distance to a transit station, are insignificant in most models. Results suggest that LRT investment may be more an economic development tool for specific neighborhoods rather than a transportation amenity. Since Charlotte is representative of a number of medium sized, lower density U.S. cities that have recently adopted or considered the adoption on LRT, these results are informative to policymakers considering LRT in other U.S. cities.

2. Related studies and conceptual framework

The literature on valuing rail transit represents a number of different cities and variations on types of properties included as well as estimated impacts. Hess and Almeida (2007) and Debrezion et al. (2007) provide extensive literature reviews across the transportation and real estate literature. The literature highlighted in these surveys with the inclusion of additional papers by Baum-Snow and Kahn (2005), McMillen and McDonald (2004), Kahn (2007), Gibbons and Machin (2005) and Redfearn (2009) generate some important trends. Specifically, there have been studies of rail transit in Atlanta, Buffalo, Calgary (Canada), Chicago, Dallas, London (UK), Los Angeles, Manchester (UK), Miami, New York, Philadelphia, Portland, Sacramento, Saint Louis, San Diego, San Francisco, San Jose, Santa Clara, Seoul (Korea), Sunderland (UK), Taipei (Taiwan) and Washington, DC. Most of these studies either measure accessibility by distance to a rail station or if a property is located within a given distance band from the rail station. Distance metrics range from examining properties adjacent to a rail station to as far as 3 miles away. The threshold is usually dictated by the local geography, location of other rail transit stations or maximum distances commuters will walk to LRT.[8] The unit of analysis varies from individual parcel, to city defined neighborhood or statistical areas, to proximity defined neighborhoods based on rail transit stations, and to census geographies. Most studies incorporate hedonic or repeat sales estimators.[9] Studies vary in testing the robustness of their results to different distance criteria or estimation models. Transacted sales data is the most common and analysis typically focuses on residential property values. The impacts of rail transit vary across studies and given the variation in proximity measures as well as empirical regression specifications, it is difficult to compare estimated impacts across the literature. Debrezion et al. (2007) standardize the measurement of impacts across the literature to find a change in property values of between −12.84% and 38.7% as one moves 820 ft closer to a rail transit station. In addition, effects are greater for commercial properties and commuter railway, and lower with the inclusion of accessibility measures to highways.

This range of estimated impacts across the literature may be a result of different study areas, but could also be due to inadequate control groups. McDonald and Osuji (1995) “note that (a) simple before-and-after method can be used provided that a control group of blocks has been selected to provide an estimate of inflation in land values.” Conceptually, a before-and-after estimation strategy requires a baseline for property value growth, which is unlikely to be the same in rail transit neighborhoods as all other neighborhoods. A few studies implicitly define control neighborhoods as those just outside the distance threshold used to determine the cutoff for rail transit impacts. Unfortunately, if the cutoff is set too small, this invalidates this type of control neighborhood. Also, properties further away from the chosen sites for rail transit stations are likely to be different if only in that they were never considered for receiving rail transit or have no right of way to establish rail transit. Dueker and Bianco (1999) use a parallel bus corridor as a control group for a study of Portland's light rail transit. They focus on a variety of metrics for neighborhood change (e.g. residential development, transportation mode usage, and vehicle ownership) including property values. They do find a positive impact on property values near LRT stations, but there is no formal statistical test of this effect. It also may be the case that a bus corridor is not a suitable alternative to the placement of a LRT alignment. The spacing for bus stops is smaller and thus accessibility effects are likely different. Cervero and Landis (1993) match office submarkets on rail transit in Atlanta and Washington, DC to other office submarkets based on observable criteria such as number of jobs, distance to downtown and perceptions of local real estate brokers. Results indicate a positive rent premium for offices located near rail transit. Gibbons and Machin (2005) and Baum-Snow and Kahn (2005) adopt a quasi-experimental approach to determine control and treatment groups. This is done by using the variation in distances to rail stations

[5] The change in zoning and land-use plans to encourage transit-oriented development as well as higher density residential along actual and proposed LRT corridors in our study area of Charlotte, highlight the public focus on LRT beyond just right-of-way and station specific infrastructure (see Charlotte-Mecklenburg Planning Commission, 2001).

[6] According to the Charlotte Chamber of Commerce, $1.8 billion of new development has been announced along the South LRT corridor (Messina, 2008).

[7] The growth in transit-oriented developments (moderate to high-density residential development that also includes employment and shopping opportunities and is located within easy walking distance of a major transit stop) around LRT stations in a number of cities are an example of this type of investment (see Cervero et al., 2004; Boarnet and Compin, 1999).

[8] This is found to be about 1/2 mile by O'Sullivan and Morrall (1996).

[9] Some exceptions include McMillen and McDonald's (2004) and Gatzlaff and Smith's (1993) use of both standard and repeat sales hedonic estimators, Redfearn (2009) and the incorporation of a Locally Weighted Regression(LWR), and Baum-Snow and Kahn (2005) and Gibbons and Machin (2005) who use a difference-in-difference estimator.

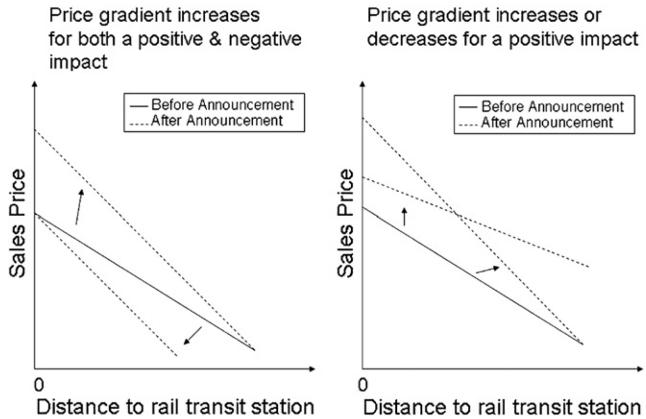

Fig. 1. Identifying impacts of rail transit.

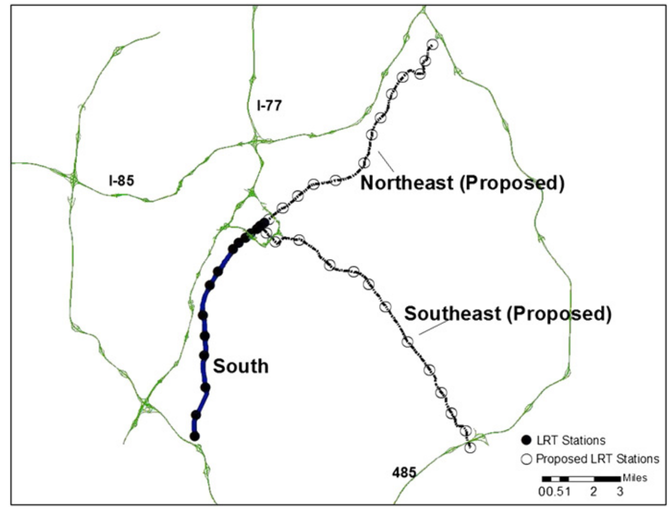

Fig. 2. Light rail transit system in Charlotte, NC.

across neighborhoods and properties from before to after the opening of new rail transit stations. This provides a nice technique to vary distance to rail transit stations, but one may still be concerned that the placement of new stations may be endogenous to more desirable or faster appreciating neighborhoods. If this was true, distance to rail transit stations would be correlated with unobserved time-varying neighborhood characteristics capitalized in housing prices.

A conceptual problem exists in using only price gradients to rail transit stations to identify the impacts of rail transit in a before-and-after methodology. Consider the two scenarios given in Fig. 1. In the case on the left, the price gradient from a rail transit station increases even though overall property values may have increased or decreased from before to after the announcement of rail transit. This could lead one to conclude a positive impact even though property values went down throughout the entire neighborhood surrounding the station. Given possible perceptions of crime[10] or nuisance related to rail transit operations and riders, a negative effect is not implausible and should be ruled out before concluding the benefits of rail transit due to a positive estimate of the price gradient.[11] The case on the right of Fig. 1 is also problematic for identification because it indicates that an increase in overall property values around rail transit stations may generate positive or negative price gradients. A flattening of the price gradient could be a result of some of the negative externalities of rail transit mentioned above or land-use externalities related to mixed land-uses or on-street parking of riders proximate to rail transit stations. Either case highlights that identification requires both an estimate of rail transit neighborhood property values as well as a price gradient to rail transit stations. Estimating changes in neighborhood property values requires a relevant control group to provide a baseline of property value changes for a similar neighborhood which did not receive rail transit stations.[12] We now describe the identification of relevant control groups based on the public planning and funding process for selecting the first alignment of LRT in Charlotte, NC.

3. Light rail in Charlotte

Charlotte's road to launching its light rail system was a long one, with initial discussions beginning in the late 1980s. In 1994, the City adopted a land use plan that explicitly targeted five transit corridors throughout the city. Land use decisions, including changes to zoning codes, were made with the intention of redeveloping properties that were in decline or underutilized, and developing new land in a manner that would guide growth to achieve higher residential densities as part of 'smart growth' and transit-oriented development principles. These corridors radiate from the central business district and reach out to the edges of Mecklenburg County.

In November 1998, Mecklenburg County residents passed a one-half cent sales tax increase. While the entire county participated in the referendum, the City of Charlotte assumed the responsibilities of the technical planning and ultimate operation of the services through the Charlotte Area Transit System (CATS). These tax revenues were dedicated to the implementation of the land use plan, and the operation and extension of current services. In September, 2000, the Metropolitan Transit Commission, consisting of the mayors and managers from the county and all six municipalities within the county as well as non-voting members from municipalities outside the county, made the official decision to establish light rail for the South transit corridor. This 9.6 mile route stretches from the downtown nearly to the county line at the southern terminus with 15 stations along the route. The South Line officially began service in November, 2007. The final construction costs were about $49 million dollars a mile with a total cost of over $450 million.[13]

The planning process for choosing the South Line identified two alternate corridors, the Northeast and Southeast.[14] These 'finalist' corridors were considered throughout the entire planning process up until the announcement of the South Line in September 2000. Additionally, the Northeast corridor was originally the preferred alignment when talks about LRT began in the late 1980s.[15] Fig. 2 highlights both the existing South Line, the proposed Northeast and

[10] See Ihlanfeldt (2003) for a study of crime and LRT in Atlanta.

[11] Bowes and Ihlanfeldt (2001) explicitly model the effects of distance bands from LRT on crime, retail development and property values. They do find different effects by distance bands as well as hypothesized LRT outcomes. Unfortunately, the lack of a control group or the use of a before and after methodology leaves results highly dependent on census tract control variables.

[12] As discussed by McMillen and McDonald (2004), there may be general equilibrium effects of rail transit. This is not formally estimated for Charlotte and thus estimates provided here are partial equilibrium. Given initial LRT ridership of 15,400 commuters a day (Charlotte Area Transit System, 2009) and a total of 435,594 employed workers (U.S. Census, 2007) in Mecklenburg County, NC for 2007, general equilibrium effects due to commuters adopting transit would result in less than 4% of commuters changing transportation mode choice and thus likely small overall impacts on traffic and air pollution.

[13] Source: Charlotte Area Transit System (2009).

[14] Information about the planning process for light rail transit in Charlotte is based on discussions with CATS officials and city of Charlotte planning documents.

[15] The two additional transit corridors targeted by the city extend to the west and north. They vary considerably from the other three corridors. Discussions surrounding the west corridor involve the implementation of a streetcar connecting downtown to the airport, while the north corridor has been considered for commuter rail to outlying bedroom communities in Davidson and Mooresville, NC.

Table 1
Neighborhood attributes.

Variable	South line		Control		Other neighborhoods	
	Mean	*sd*	Mean	*sd*	Mean	*sd*
Population	3330	*1959*	3953	*2506*	2596	*1805*
Population density	4.562	*2.069*	4.824	*2.416*	3.029	*2.368*
Percent homes — owner occupied	0.483	*0.250*	0.510	*0.226*	0.605	*0.251*
Median household income	39,702	*19,062*	42,872	*23,391*	51,801	*28,953*
Portion of households on food stamps	0.075	*0.104*	0.073	*0.086*	0.071	*0.110*
Portion of under 18 — school dropouts	0.095	*0.051*	0.100	*0.063*	0.083	*0.063*
% of 7th, 8th grade test scores at/above grade level	0.504	*0.242*	0.511	*0.248*	0.568	*0.274*
Portion of population over 65 years old	0.116	*0.049*	0.113	*0.057*	0.112	*0.058*
Portion of population under 18 years old	0.096	*0.085*	0.104	*0.116*	0.091	*0.120*
% of residents ≤1/4 mile of a bus stop	0.780	*0.228*	0.770	*0.317*	0.517	*0.421*
Property crime index	1.491	*1.025*	1.128	*0.707*	1.025	*0.850*
Violent crime index	1.631	*2.016*	1.436	*1.504*	1.303	*1.608*
N	23		43		114	

All data based on the 2000 Charlotte Neighborhood Quality of Life Survey. Neighborhoods are based on NSAs (Neighborhood Statistical Areas), which represent urban planning units for the city of Charlotte. Three NSAs are excluded due to missing data.
South Line and control neighborhoods are designated based on a NSA boundary within 1 mile of a proposed or actual LRT station.

Southeast corridors as well as their existing and proposed LRT stations.[16] All three alignments contain a number of similarities including connecting downtown to residential neighborhoods as well as using existing transportation corridors and right of ways to determine the placement of the LRT alignment. The two alternate alignments (Northeast and Southeast) serve as the control group in subsequent analysis.

Table 1 highlights the characteristics of neighborhoods that contain or are located within 1 mile[17] of LRT stations for these corridors. This neighborhood data is based on the Neighborhood Statistical Areas (NSAs) from the city of Charlotte's 2000 Neighborhood Quality of Life Study.[18] This neighborhood data is primarily Census 2000 geographies and data, which have been supplemented by the city of Charlotte. It allows us to include variables for property and violent crimes as well as the portion of residents that use bus transit in 2000.[19] As shown in Table 1, the South Line and control neighborhoods exhibit similar socio-economic characteristics across a number of variables that may impact the use of transit and property values. The only variables that experience any substantial difference between the South Line and control neighborhoods are population, property and violent crimes, but the means for these variables are not statistically different at even the 10% level.[20]

Table 1 highlights the characteristics of all other neighborhoods[21] in the city of Charlotte. Comparing the South Line (Treatment) neighborhoods with all other Charlotte neighborhoods is likely to lead to mistaken inference given that neighborhoods that receive light rail transit have fundamentally different characteristics than all other neighborhoods. Specifically, South Line neighborhoods are more populated, denser, lower ownership, lower income, higher bus transit ridership and higher crime than all other neighborhoods.

4. Standard hedonic model

Initially, we adopt a standard hedonic model to estimate both neighborhood property values and price gradient effects from the introduction of LRT. In this application, let the standard hedonic price Eq. (1) estimates the relationship between $P_{i,t}$ = the transaction price for housing unit i in period t and $X_{i,t}$ = a vector of structural characteristics for property i in period t; $N_{i,t}$ = a vector of neighborhood characteristics for property i in period t; $G_{i,t}$ = an indicator for property i belonging to a South Line neighborhood or the Euclidean distance from housing unit i to the nearest LRT station in period t; $D_{i,j}$ = 1 if property i sold in period j ($j = 1, 2, \ldots, n_j$), and equals 0 otherwise; and $\varepsilon_{i,t}$ = error term for property i in period t. We incorporate a total of $n_j = 58$ time periods representing each quarter from the beginning of 1994 through June 2008. We estimate coefficients based on mean values of covariates for the pre and post LRT announcement periods given by $LRTAnn = 1$ after the announcement of LRT in 2000 and 0 otherwise. Our difference-in-difference estimator is given by the interaction of $G_{i,t}$ and $LRTAnn$ and thus θ is our coefficient of interest.

$$ln\left(P_{i,t}\right) = \alpha + \beta_1 X_{i,t} + \beta_2 N_{i,t} + \beta_3 G_{i,t} + \theta G_{i,t} * LRT\,Ann_{i,t} + \sum_{j=1}^{n_j} \delta_j D_{i,j} + \varepsilon_{i,t}. \quad (1)$$

Table 2 provides price per square foot trends using transacted sales data for single-family homes, condominiums and commercial properties. The before and after time periods correspond to the announcement of the South line in 2000. Across property types and neighborhoods, we see variation in sales price appreciation. For single-family properties, South Line neighborhoods contain a 60.2% growth in sales price per square foot followed by Control neighborhoods with 53.6% growth. All other neighborhoods contained a substantially smaller price appreciation of 28.0%. Across property types, South Line neighborhoods experienced greater growth in property values than either control or other neighborhoods. Additionally, pre-announcement prices per square foot do vary between South Line and control neighborhoods, which highlight the need to account for initial neighborhood differences in the stock of properties.

[16] Proposed LRT stations are based on discussions in late 2008 regarding potential expansions of LRT to the Northeast and Southeast corridors.
[17] Distances greater than 1 mile are problematic for this research because the scale of the city and the three corridors provides too many overlapping treatment and control neighborhoods at greater distances.
[18] In 1993, the City of Charlotte subdivided the city into 183 small, mutual exclusive planning districts called Neighborhood Statistical Areas (NSAs). The boundaries for the NSA began as Census blocks and then were modified to encompass the perceived neighborhood boundaries of residents and real estate professionals in Charlotte. Therefore, these geographies are better served at defining neighborhoods as perceived by real estate buyers than Census geographies. The city uses the boundaries of these the areas for various economic, social, population, health, and crime tracking purposes and to assist in developing neighborhood specific policy plans.
[19] The two crime variables are based on a location quotient given by the ratio of crimes per capita in a given neighborhood to crimes per capita for the entire city. Therefore a value of one indicates average crime per capita in a given NSA. The bus transit variable provides the percent of NSA residents within a quarter mile of a bus transit stop. See Charlotte's Neighborhood Quality of Life Study website (http://www.charmeck.org/city/charlotte/nbs/communitycommerce/QOL) for more details on these NSA variables.
[20] We initially considered investigating the impact of LRT on neighborhood composition, but given the short time span of available data and some preliminary analysis of neighborhood trends, we decided to leave that analysis for future research.
[21] This is defined as neighborhoods not within 1 mile of the South Line or control corridors.

Table 2
Property value trends 1994–2008.

Sales price per square foot	Pre announcement	Post announcement	Post–pre announcement	
Mean	Jan. 1994 to Sept. 2000	Oct 2000 to June 2008	#	%
Single-family ($n=151{,}896$)				
South Line neighborhoods (n = 4799)	$80.85	$129.50	$48.65	60.2
Control neighborhoods (n = 10,510)	$68.70	$105.53	$36.83	53.6
Other neighborhoods (n = 136,587)	$70.68	$90.46	$19.78	28.0
Condominiums ($n=37{,}429$)				
South Line neighborhoods (n = 3294)	$80.36	$203.14	$122.78	152.8
Control neighborhoods (n = 5480)	$72.73	$125.59	$52.86	72.7
Other neighborhoods (n = 28,655)	$103.35	$169.62	$66.27	64.1
Commercial ($n=4352$)				
Treatment neighborhoods (n = 627)	$75.30	$350.43	$275.13	365.4
Control neighborhoods (n = 1070)	$146.14	$332.95	$186.81	127.8
Other neighborhoods (n = 2655)	$61.57	$188.05	$126.48	205.4

We now turn our attention to a repeat sales hedonic model, which allows us to track a common stock of properties from before to after the announcement of light rail transit.

5. Repeat sales hedonic model

The repeat sales model begins with the initial hedonic specification given in Eq. (1). We then subtract the sale of property i in time $t-1$ from the sale of property i in time t. Assuming there were no changes in the structural or neighborhood characteristics of housing units between sales[22] (e.g. $X_{i,t}=X_{i,t-1}=X_i$ and $N_{i,t}=N_{i,t-1}=N_i$) and as a starting point no changes in LRT serving housing units between sales (e.g. $G_{i,t}=G_{i,t-1}=G_i$), the standard repeat sales specification[23] becomes:

$$ln\left(P_{i,t}\right)-ln\left(P_{i,t-1}\right)=\sum_{j=1}^{n_j}\delta_j D^*_{i,j}+\varepsilon_{i,t}-\varepsilon_{i,t-1} \tag{2}$$

where $D^*_{i,j}=-1$ if property i sold for the first time in period j ($j=1,2,\ldots,n_j$); equals $+1$ if property i sold for the second time in period j; and equals zero otherwise.

Goetzmann and Spiegel (1995) separate capital appreciation for residential properties into temporal and fixed components and attribute the fixed component of housing return to the repairs that typically take place when a house is bought or sold. To address this issue, they show the importance of including a series of dummies based on quartiles of transacted sales prices. As applied in Billings and Thibodeau (2011), we incorporate a series of intercepts that correspond to different deciles of $P_{i,t-1}$. In our model, this is equivalent to including $\sum_{k=1}^{10}\alpha_k$ where k indicates decile of $P_{i,t-1}$ across all properties in repeat sales estimation.[24] Given the absence of historic structural information, this method helps control for a property's potential to be renovated/improved in a repeat sales framework.

$$ln\left(P_{i,t}\right)-ln\left(P_{i,t-1}\right)=\sum_{k=1}^{10}\alpha_k+\theta\left[G_{i,t}-G_{i,t-1}\right]+\sum_{j=1}^{n_j}\delta_j D^*_{i,j}+\varepsilon_{i,t}-\varepsilon_{i,t-1}. \tag{3}$$

To examine the impact of the South Line on appreciation rates, we allow G_i to change between sales that occur before and after the announcement of LRT. Eq. (3) provides the estimation equation adopted for repeat sales estimates. To highlight property appreciation trends for the South Line and control alignments, we estimate a simple quarterly repeat sales index for treatment neighborhoods (within 1 mile of South alignment stations), control neighborhoods (within 1 mile of Northeast or Southeast alignment stations), and all other repeat sales properties in Mecklenburg County. Fig. 3 plots these indices with the horizontal line indicating the announcement date of September 2000. From 1994 to 2008, the treatment neighborhoods experienced property appreciation of 90%, the control neighborhoods appreciated 52% and all other residential properties appreciated 50%.

The three groups exhibit similar property appreciation trends from 1994 to 1997. Between 1998 and the announcement date, the South Line neighborhood experienced higher property values. The repeat sales index converges in value for the South Line and control neighborhoods right after the announcement in 2001–2002 and then diverges in value from 2003 to 2008. The index for all properties remains smaller than both South Line and control neighborhoods from 2000 to 2008. Ideally, the South Line and control neighborhoods would contain identical price indices before the announcement, but that is not a necessary condition for a relevant control group with a before-and-after estimator. A control group needs to experience similar property value appreciation rates as the treatment (South Line) group would in the absence of receiving LRT. From 1998 to the announcement in 2000, South Line and control neighborhoods

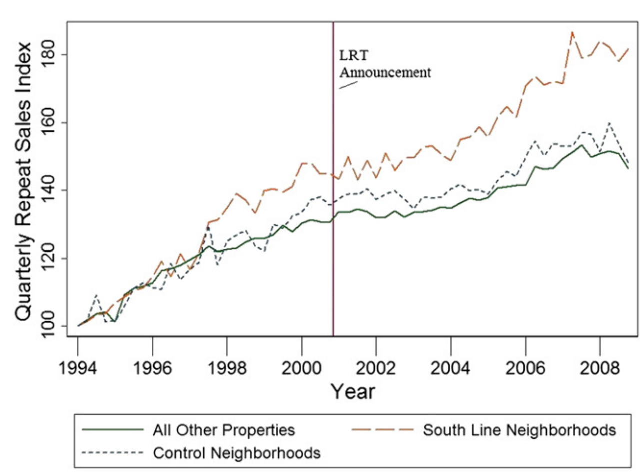

Fig. 3. Quarterly repeat sales index — Charlotte, NC.

[22] For other papers that develop the relationship between the hedonic house price equation and the repeat sales equation, see Case and Quigley (1991), Quigley (1995), Hill et al. (1997), Clapp and Giaccotto (1998).

[23] The standard repeat sales house price index (e.g. Bailey et al., 1963; Case and Shiller, 1987; Case and Shiller, 1989; Calhoun, 1996) requires the additional assumption that the hedonic coefficients for the structural, neighborhood and proximity to LRT characteristics are temporally invariant (e.g. $\alpha_t=\alpha_{t-1}$, $\beta_t=\beta_{t-1}$, $\eta_t-\eta_{t-1}$ and $\gamma_t=\gamma_{t-1}$).

[24] In the end, our results are unchanged with the exclusion of $\sum_{k=1}^{10}\alpha_k$.

experienced total appreciation rates of 8.0% and 8.4% respectively. This indicates similar property value growth for the South Line and control corridors leading up to the announcement. From the announcement to 2008, the total appreciation rates for the South Line and control neighborhoods are 28.3% and 10.0% respectively. In subsequent sections, we formally test if higher property value appreciation in the South Line after the announcement of LRT holds across a range of hedonic specifications and with the inclusion of a rich set of neighborhood and structural covariates.

6. Property data

The Mecklenburg County assessor's office contains detailed electronic data on all parcels in its jurisdiction, which includes the entire city of Charlotte. This data provides a number of structural characteristics about a property as well as geographic coordinates of each parcel and complete records of any sales transactions from 1994 to 2008. The assessor's data distinguishes between single-family homes, condominiums and commercial properties. Data cleaning removed a total of 8467 parcels (or 2.7% of all parcels) with missing structural information and single-family parcels with lot sizes greater than 5 acres or residential properties without bathrooms. A total of 80,240 parcels are not included in hedonic analysis because they contain no recorded property sales, represent non-qualified sales or sales transactions of less than $20, 000. In addition, the repeat sales estimator included a parcel more than once if it contained more than two sales transactions and any paired sales transactions for a given parcel could not be less than two years apart. These restrictions attempt to remove large scale renovations or 'flips' from the dataset. Table 2 contains the relevant number of observations by property type.

Additional property characteristics computed using Mecklenburg County geospatial data include distance to the Downtown[25] (*Distance to CBD*) and distance to the closest of Interstates 77, 85 or 485 (*Distance to Interstate*). There are 55 unique building attributes (based on subclassifications within attributes for foundations, exterior walls, heating/AC, style of home, number of stories) available in this dataset and indicator variables for each of them is included in later regressions analysis.

In order to identify relevant properties along the three corridors (South, Northeast and Southeast), we computed the Euclidean distances from the centroid of each parcel to its nearest LRT station (*Distance to LRT*).[26] The location of LRT stations for the existing South alignment was provided at the announcement in 2000 and did not vary during the construction period through the opening in 2007. The location of proposed LRT stations was unknown along the proposed corridors (Northeast, Southeast) in 2000, but a number of potential LRT station locations were considered in 2008 as part of the initial planning process for future extensions of LRT.[27] Irrespective of exact station locations, neighborhood areas can still be defined based on the Northeast and Southeast alignments and more recently considered station locations.

7. Empirical results

Initial results provide estimates for the hedonic price estimator and later analysis provides results for additional hedonic specifications as well as the repeat sales estimator. We begin by estimating a neighborhood impact of LRT to determine how neighborhood property values responded to the announcement of LRT. Then, we estimate how the price gradient to actual LRT stations changes from before to after the announcement of LRT. Neighborhoods are defined at distances of 1 mile and 1/2 mile from LRT stations. Ideally we would have included smaller distance intervals, but there are few observations near LRT stations within 1/4 mile or less for single-family as well as commercial properties.[28] For example, there are only 114 single-family property transactions and 49 commercial properties within a 1/4 mile of LRT stations after the announcement of LRT. This decreases to 1 single-family property and 7 commercial properties within a 1/8 mile. This is mainly attributed to the presence of road and rail related infrastructure around LRT alignments.

7.1. Single-family properties

Table 3 provides hedonic estimates for single-family homes within 1 mile of the South Line stations or proposed LRT stations. The difference-in-difference coefficient is given by *LRTAnn∗SouthLine*, the interaction of an indicator for the time period after the announcement of the South Line (after September 2000) and an indicator equal to one for a property in a South Line neighborhood. Different subsets of the data are given in column headings and results indicate a positive impact of 4.0%[29] for 1 mile neighborhoods, but this disappears for neighborhoods defined by being within 1/2 mile of a LRT station.[30] This effect indicates some appreciation in the existing LRT neighborhoods relative to proposed LRT neighborhoods. This benefit may be negated in close proximity to the LRT stations, which may indicate a nuisance effect for single-family homes near LRT. The nuisance may be related to the expectation of increased traffic, parking or people close to LRT stations. For single-family properties within less than a 1/2 mile, the value of a quieter neighborhood may outweigh any benefits of access to LRT and/or potential new retail, restaurants around a LRT station. The third regression in Table 3 breaks down results for three time periods of economic interest.[31] The periods are pre-announcement (before September 2000), the two years (September 2000 through 2002) following the announcement and 2003 through 2008. Results indicate that impacts are not present until after 2002, which is not surprising given that land markets need time to adjust to new information regarding light rail transit. The delay in impacts is consistent with past research that tests for this effect (McMillen and McDonald, 2004).

Estimated changes in price gradients to LRT stations are insignificant across models. The coefficient of interest is given by *LRTAnn∗DistanceLRT*, which is the interaction between an indicator for a sale after the announcement of the South Line and Distance to LRT

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[25] The center of Charlotte and its downtown is recognized as the intersection of two former Native American trading routes — Trade and Tryon streets.

[26] Alternatively, L_1 or Manhattan distance using geospatial data on streets provides only minimal differences in relative distances to LRT across properties in LRT neighborhoods. For a subsample of properties, we found a similar distribution of distances to LRT between Euclidean and Manhattan distance metrics with Manhattan distances generating a larger mean value.

[27] Any concern that LRT may have been capitalized in control corridors is minimal given the high level of uncertainty for both the funding and exact LRT station locations from the announcement to the end of our dataset in 2008.

[28] This also excluded this research from testing if properties adjacent to a LRT alignment experienced a nuisance effect from the LRT tracks themselves. Chen et al. (1998) found this to be insignificant, but subsequent researchers sometimes include a variable for distance to LRT alignment (see McMillen and McDonald, 2004; Kilpatrick et al., 2007).

[29] Coefficients (θ) differ from estimated impacts due to the use of the Halvorsen and Palmquist (1980) correction for the interpreting dummy variable coefficients in a semilogarithmic equation. Estimated impact is given by ($e^{\theta}-1$) for all reported impacts.

[30] Control variables are consistent with the literature and find a positive but nonlinear impact of square footage, a nonlinear negative impact of age, a nonlinear and negative impact of distance (in miles) to the CBD and a positive impact of having a fireplace on sales price.

[31] McMillen and McDonald (2004) use the Akaike (1973) information criterion to determine relevant groupings of the data into time periods. This is statistical a better approach, but does not ensure economically meaningful cutoffs to the data. The research presented here is interested in post announcement impacts and if these impacts immediately follow the announcement or require a few years to be capitalized in land market transactions.

Table 3
Single-family hedonics.

Dep Var = ln(Sales price)	Neighborhood			Price gradient	
	1 mile	1/2 mile	1 mile	1 mile	1/2 mile
LRTAnn ∗ SouthLine	0.0397***	−0.0124			
	(0.0102)	(0.0188)			
LRTAnn-2002 ∗ SouthLine			−0.0244		
			(0.0139)		
Year2003–2008 ∗ SouthLine			0.0692***		
			(0.0102)		
LRTAnn ∗ DistanceLRT				−0.0073	−0.0158
				(0.0346)	(0.1380)
DistanceLRT (miles)				0.1367***	0.1491
				(0.0401)	(0.1370)
SouthLine	0.0861***	0.1604***	0.0796***		
	(0.0099)	(0.0191)	(0.0093)		
Lot size (acres)	0.1496***	0.1534***	0.1502***	0.2304***	0.3433***
	(0.0171)	(0.0315)	(0.0170)	(0.0360)	(0.0921)
Fullbaths	0.0029	−0.0064	0.0024	−0.0030	0.0072
	(0.0059)	(0.0117)	(0.0059)	(0.0085)	(0.0163)
Bedrooms	0.0260***	0.0074	0.0260***	0.0102	−0.0009
	(0.0037)	(0.0061)	(0.0037)	(0.0069)	(0.0111)
sq ft (000 s)	0.4108***	0.4280***	0.4116***	0.4230***	0.3348***
	(0.0142)	(0.0588)	(0.0142)	(0.0361)	(0.0709)
$sqft^2$ (0000 s)	−0.0189***	−0.0283*	−0.0189***	−0.0256***	−0.0160
	(0.0025)	(0.0158)	(0.0024)	(0.0077)	(0.0165)
age	−0.0221***	−0.0242***	−0.0219***	−0.0182***	−0.0228***
	(0.0009)	(0.0016)	(0.0009)	(0.0018)	(0.0043)
age^2 (000 s)	0.3973***	0.4162***	0.3907***	0.3052***	0.3497***
	(0.0221)	(0.0392)	(0.0221)	(0.0427)	(0.0917)
age^3 (0000 s)	−0.0018***	−0.0019***	−0.0018***	−0.0013***	−0.0014**
	(0.0002)	(0.0003)	(0.0002)	(0.0003)	(0.0005)
Fireplace	0.1025***	0.0903***	0.1020***	0.0575***	0.0199
	(0.0054)	(0.0092)	(0.0054)	(0.0091)	(0.0142)
Distance to CBD (miles)	−0.2132***	−0.1847***	−0.2150***	−0.5272***	−0.5437***
	(0.0075)	(0.0144)	(0.0075)	(0.0278)	(0.0971)
Distance to CBD squared	0.0149***	0.0110***	0.0151***	0.0431***	0.0432***
	(0.0006)	(0.0014)	(0.0006)	(0.0022)	(0.0092)
Distance to Interstate (miles)	−0.0005	0.0009	−0.0000	0.0754***	0.1150*
	(0.0020)	(0.0045)	(0.0019)	(0.0226)	(0.0678)
Constant	11.1533***	11.2640***	11.1502***	13.4080***	10.6862***
	(0.2056)	(0.2015)	(0.1993)	(0.3812)	(1.3097)
Neighborhood covariates	Yes	Yes	Yes	Yes	Yes
Year and quarter of sale dummy	Yes	Yes	Yes	Yes	Yes
Indicators for building attributes	Yes	Yes	Yes	Yes	Yes
Observations	14,162	4546	14,162	4762	1583
R-squared	0.809	0.778	0.810	0.868	0.851

Robust standard errors in parentheses. Indicators for building attributes contain 55 unique measures of foundation type, stories, exterior wall, heating, and air-conditioning. Estimated price gradients are based only of South Line neighborhoods.
*** $p<0.01$.
** $p<0.05$.

(miles).[32] These effects indicate insignificant impacts of distance (miles) to the LRT station.[33] Insignificant price gradients may be due to other land-uses near LRT stations limiting the access amenity for residential properties. This highlights the importance of both neighborhood and price gradients. The introduction of LRT appears to generate a positive neighborhood price appreciation, but not as an access amenity for LRT riders. New development provides an additional component of LRT impacts, so we examined the trend for new construction from before to after the announcement of LRT for both South Line and control neighborhoods. Fig. 4 shows the number of single-family housing units by year of construction from 1994 to 2007 for South Line relative to control neighborhoods. We see that the number of new homes were constant for South Line neighborhoods

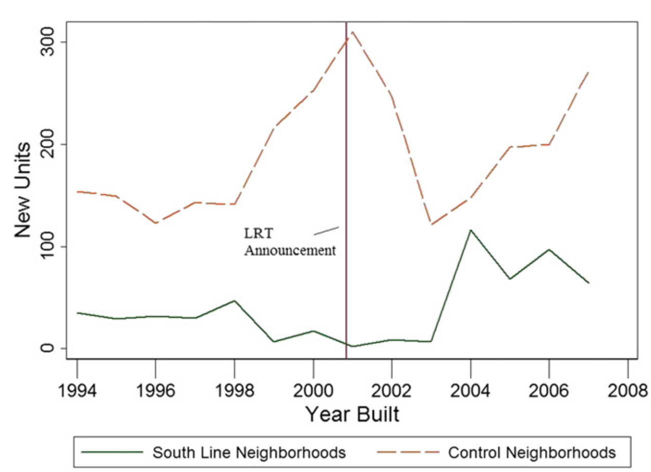

Fig. 4. New single-family homes within 1 mile of LRT stations.

[32] Since there are no proposed LRT stations in control corridors at the time of announcement, this analysis only included a before and after methodology for properties along the South corridor in order to estimate price gradients.
[33] Unreported impacts including *DistanceLRT* squared as well as its interaction with *LRTAnn* are also insignificant.

Table 4
Condominium hedonics.

Dep Var = ln(Sales price)	Neighborhood			Price gradient	
	1 mile	1/2 mile	1 mile	1 mile	1/2 mile
LRTAnn∗SouthLine	0.1069**	0.1258**			
	(0.0431)	(0.0549)			
LRTAnn-2002∗SouthLine			0.0663		
			(0.0422)		
Year2003–2008∗SouthLine			0.1183***		
			(0.0428)		
LRTAnn∗DistanceLRT				−0.1510	−0.0887
				(0.1302)	(0.4485)
DistanceLRT (miles)				−0.0083	−0.1279
				(0.1694)	(0.4926)
South Line	0.0204	0.0292	0.0182		
	(0.0498)	(0.0618)	(0.0473)		
CondoCount	−0.0006	−0.0004	−0.0006	−0.0009	−0.001
	(0.0004)	(0.0005)	(0.0004)	(0.0005)	(0.0006)
Fullbaths	0.0821***	0.0979***	0.0815***	0.1309***	0.0976**
	(0.0192)	(0.0240)	(0.0192)	(0.0363)	(0.0461)
Bedrooms	−0.0105	−0.0237	−0.0104	−0.0296**	−0.0120
	(0.0103)	(0.0159)	(0.0103)	(0.0150)	(0.0146)
sq ft (000 s)	1.0694***	1.1650***	1.0737***	1.0745***	1.1941***
	(0.0569)	(0.0660)	(0.0567)	(0.0836)	(0.0669)
$sqft^2$ (0000 s)	−0.1320***	−0.1509***	−0.1334***	−0.1387***	−0.1536***
	(0.0141)	(0.0186)	(0.0142)	(0.0229)	(0.0202)
age	−0.0223***	−0.0124***	−0.0223***	−0.0107*	−0.0014
	(0.0026)	(0.0035)	(0.0026)	(0.0057)	(0.0054)
age^2 (000 s)	0.3543***	0.1350	0.3559***	0.0871	−0.1254
	(0.0837)	(0.1150)	(0.0833)	(0.1491)	(0.1384)
age^3 (0000 s)	−0.0014**	−0.0002	−0.0014**	0.0000	0.0013
	(0.0007)	(0.0009)	(0.0007)	(0.0011)	(0.0010)
Fireplace	0.0418**	0.0145	0.0413**	0.0352	0.0560
	(0.0164)	(0.0203)	(0.0163)	(0.0259)	(0.0475)
Distance to CBD	−0.2668***	−0.1596**	−0.2672***	−0.1233	−0.4365
	(0.0272)	(0.0764)	(0.0270)	(0.1350)	(0.3302)
Distance to CBD squared	0.0182****	0.0062	0.0183***	0.0183	0.0180
	(0.0030)	(0.0095)	(0.0031)	(0.0138)	(0.0846)
Distance to Interstate (miles)	−0.0067	−0.0554**	−0.0073	0.0271	0.5046***
	(0.0114)	(0.0282)	(0.0114)	(0.1410)	(0.1903)
Constant	10.5692***	11.3970***	10.5557***	12.4408***	9.0314**
	(0.1753)	(0.4434)	(0.1761)	(0.9739)	(3.6290)
Neighborhood covariates	Yes	Yes	Yes	Yes	Yes
Year and quarter of sale dummy	Yes	Yes	Yes	Yes	Yes
Indicators for building attributes	Yes	Yes	Yes	Yes	Yes
Observations	6547	3708	6547	2487	1713
R-squared	0.915	0.926	0.915	0.942	0.950

Robust standard errors in parentheses clustered by condominium complex.
Indicators for building attributes contain 55 unique measures of foundation type, stories, exterior wall, heating, and air-conditioning. Price gradient is based only of South Line neighborhoods.
Estimated price gradients are based only of South Line neighborhoods.
*** $p<0.01$.
** $p<0.05$.

until 2003, when we saw an increase in both South Line and control neighborhoods. There appears to be a limited relationship between the announcement of LRT and new single-family homes.

7.2. Condominium properties

Since impacts of LRT likely vary by property type, Table 4 provides results for condominiums within 1 mile of South Line or control stations. An additional variable (*CondoCount*) is included in all condominium hedonic specifications to indicate the number of condominiums on a given parcel.[34] In comparison to single-family properties, results are considerably larger with the 1 mile neighborhoods providing a positive impact of 11.3%.[35] With this property type, the effect grows with smaller distance defined neighborhoods and an estimated impact of 13.4% for 1/2 mile neighborhoods. The greater estimated neighborhood benefits for condominiums may be due to lower disamenities from LRT related nuisances or part of new residential development around LRT stations. It may be the case that since condominium households represents a higher proportion of non-family and single households, parking[36] and safety issues may be less costly to them.

The presence of new development is indicated by the fact that 43.7% of all condominiums within 1 mile of actual LRT stations were built since 2001.[37] In control neighborhoods only 32.1% of condominiums sold within 1 mile of proposed LRT stations were built since 2001. Fig. 5 displays the trends for new construction and highlights that South Line neighborhoods experienced more new units after the

[34] This control variable provides a measure of the size of a condominium complex, which attempts to capture common property amenities (e.g. swimming pool, gym, etc.) and homeowner association fees.

[35] The larger capitalization of LRT for condominiums versus single-family homes is consistent with Duncan (2008)'s study of rail transit in San Diego, CA.

[36] Non-family households likely contain fewer or smaller vehicles.

[37] These numbers are based on properties built and classified as multi-family units by the Mecklenburg county assessor's office.

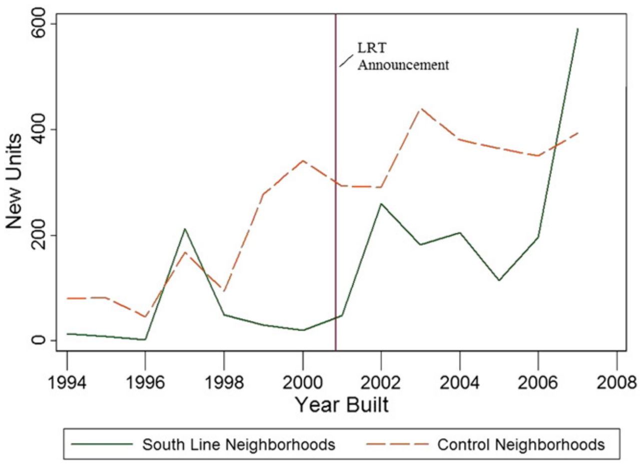

Fig. 5. New condominiums within 1 mile of LRT stations.

announcement of LRT and control neighborhoods saw a consistent increase in new condominiums from before to after the announcement of LRT. Consistent with single-family results, condominiums have large impacts after 2002 relative to 2000 and 2001. Estimated price gradient changes are insignificant across models and indicate no impact based on proximity to LRT stations. Additionally, control variables for bathrooms, square feet of living space, age and distance to CBD all have the expected signs.

7.3. Commercial properties

Table 5 provides results for commercial properties within 1 mile of South Line or control stations. Since commercial properties incorporate a number of businesses that may be impacted differently by LRT, we breakdown results into two categories: retail/restaurants/hotels and office properties. Further disaggregation is not possible given the limited number of commercial properties with sales transactions along the South Line and control corridors. Additionally, regressions cannot include building attribute indicators nor a few variables that are not available as part of commercial property records. Results are broadly consistent across regressions with no estimated neighborhood impacts and insignificant estimated changes in price gradients to LRT stations. Furthermore, there are no clear trends for the limited number of new commercial properties across South Line and control neighborhoods both before and after the announcement of LRT. The insignificant impact of LRT on commercial properties across models may be a result of two factors. First, the limited number of observations and heterogeneity in commercial property types (e.g. office, retail, restaurants, etc.) may limit our ability to detect LRT impacts. Second, commercial impacts may only occur after residential development in LRT neighborhoods, as new businesses respond to changing consumer markets. This effect may not materialize until

Table 5
Commercial hedonics.

Dep Var = ln(Sales price)	Neighborhood			Price gradient		
	All commercial	Office	Retail, hotel and restaurants	All commercial	Office	Retail, hotel and restaurants
	1 mile	1 mile	1 mile	1 mile	1 mile	1 mile
LRTAnn∗SouthLine	0.1219	−0.0708	0.0485			
	(0.1285)	(0.1483)	(0.2148)			
South Line	0.1137	0.0419	0.3014			
	(0.1189)	(0.1369)	(0.2073)			
LRTAnn∗DistanceLRT				0.4154	0.4076	0.0984
				(0.4595)	(0.6732)	(0.7441)
DistanceLRT (miles)				0.2002	0.1442	0.1602
				(0.4305)	(0.6035)	(0.6554)
Lot size (acres)	0.1194***	−0.0682	0.1187***	0.1078***	0.0008	0.1132***
	(0.0108)	(0.0393)	(0.0099)	(0.0113)	(0.0756)	(0.0241)
sq ft (000 s)	0.0268***	0.0847***	0.0169***	0.0259***	0.0708***	0.0213***
	(0.0024)	(0.0066)	(0.0026)	(0.0031)	(0.0087)	(0.0054)
$sqft^2$ (0000 s)	−0.0000***	−0.0003***	−0.0000***	−0.0000***	−0.0003***	−0.0000***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
age	0.0260***	0.0078	0.0381***	0.0269**	0.0248	0.0116
	(0.0068)	(0.0101)	(0.0103)	(0.0106)	(0.0158)	(0.0298)
age^2 (000 s)	−0.8339***	−0.4032*	−1.3833***	−0.8262***	−0.7312**	−0.6788
	(0.1647)	(0.2223)	(0.2950)	(0.2559)	(0.3503)	(1.0880)
age^3 (0000 s)	0.0058***	0.0035**	0.0103***	0.0058***	0.0054***	0.0061
	(0.0011)	(0.0014)	(0.0022)	(0.0016)	(0.0021)	(0.0093)
Distance to CBD (miles)	−0.3292***	−0.1929	−0.3709***	−0.6199***	−0.5611	−0.7007**
	(0.0757)	(0.1332)	(0.0987)	(0.1645)	(0.6266)	(0.3432)
Distance to CBD squared	0.0328***	0.0152	0.0418***	0.0638***	0.0462	0.0709**
	(0.0075)	(0.0115)	(0.0096)	(0.0161)	(0.0525)	(0.0304)
Distance to Interstate (miles)	0.0367	0.0196	0.0769*	−0.2271	0.3872	−0.1748
	(0.0367)	(0.0616)	(0.0450)	(0.2080)	(0.4668)	(0.4815)
Constant	12.5108***	11.6825***	14.0474***	13.7246***	−1.0649	11.8721**
	(0.5755)	(0.7277)	(0.7615)	(2.5572)	(17.9142)	(5.1589)
Neighborhood covariates	Yes	Yes	Yes	Yes	Yes	Yes
Year and quarter of sale dummy	Yes	Yes	Yes	Yes	Yes	Yes
Indicators for building attributes	N/A	N/A	N/A	N/A	N/A	N/A
Observations	1009	580	429	354	215	139
R-squared	0.623	0.684	0.793	0.760	0.836	0.870

Robust standard errors in parentheses. Estimated price gradients are based only of South Line neighborhoods.

*** $p<0.01$.

** $p<0.05$.

Table 6
Robustness of Results — Single-Family Properties.

Coefficient of interest	NE and SE control corridors		NE control corridor		PSM control neighborhoods		Walk-N-Ride		New properties
	Hedonic	Repeat sales	Hedonic	Repeat sales	Hedonic	Repeat sales	Hedonic	Repeat sales	Hedonic
	1 mile	1 mile	1 mile	1 mile	1 mile	1 mile	1 mile	1 mile	1 mile
Neighborhood effects									
LRTAnn∗SouthLine	0.0397***	0.0447***	0.0397***	0.0418**	0.0020	0.0507***	0.1011***	0.0106	−0.0691
	(0.0102)	(0.0134)	(0.0138)	(0.0181)	(0.0126)	(0.0143)	(0.0228)	(0.0257)	(0.0398)
Neighborhood effects by time groups									
LRTAnn-2002∗SouthLine	−0.0244	−0.0364	−0.0249	−0.0161	−0.0463***	−0.0146	−0.0228	−0.1118***	−0.1534
	(0.0139)	(0.0195)	(0.0176)	(0.0215)	(0.0165)	(0.0196)	(0.0347)	(0.0409)	(0.0872)
Year2003–2008∗SouthLine	0.0692***	0.0344**	0.0873***	0.0243	0.0238*	0.0326*	0.1345***	0.0311	−0.0680
	(0.0102)	(0.0156)	(0.0140)	(0.0190)	(0.0132)	(0.0168)	(0.0222)	(0.0316)	(0.0421)
Observations	14,162	6646	8313	3469	9549	5219	6326	3058	1596
Price gradient effects (1)									
LRTAnn∗DistLRT	−0.0073	0.0169	−0.0073	0.0169	−0.0073	0.0169	−0.1204	−0.0338	−0.1501
	(0.0346)	(0.0249)	(0.0346)	(0.0249)	(0.0346)	(0.0249)	(0.0921)	(0.0593)	(0.3331)
Observations	4762	2457	4762	2457	4762	2457	1283	720	347

Dependent variable = ln(Sales price) for hedonic specifications and ln(Sales price (t)) − ln(Sales price (t − 1)) in repeat sales specifications.
Results indicate separate regressions for the three sets of regressions indicated by italicized row headings. Each column indicates the data subset used for corresponding results.
All hedonic regressions incorporate the same variables from estimated models in Table 3 and column 1 restates results from Table 3.
Repeat Sales regressions also include previous price deciles and a indicator for observations that include more than two sales.
Propensity Score Matching (PSM) Models are based on the five nearest neighbors within a propensity score of 0.05.
Control neighborhood observations are weighted by the frequency upon which they are matched with South Line neighborhood observations.
(1) Price gradient estimates are unchanged across the three sets of control groups because LRTAnn∗DistLRT is only estimated on South Line neighborhoods.
*** $p<0.01$.
** $p<0.05$.

later years, well after the opening of LRT in 2007 and beyond available years for data analysis.

8. Repeat sales and robustness of results

Tables 6 and 7 present coefficients of interest for repeat sales as well as additional standard hedonic specifications for single-family properties and condominiums respectively.[38] Results are organized similarly for both property types and we only report the coefficient of interest based on separate regressions conducted for each column heading. We provide results for overall neighborhood effects, neighborhood effects by time periods and price gradient effects. We begin by reporting results from the full sample of South Line and control corridor properties for hedonic and repeat sales estimators.

In order to test the sensitivity of our results to alternatively defined control groups, we begin by simply removing the Southeast Corridor and adopt only the Northeast corridor for the control group. The South Line and Northeast corridors provide spatially similar alignments in that they both run along secondary commercial streets from downtown and are aligned parallel to Interstates 77 and 85. Additionally, we create a second type of control group by implementing a propensity score matching (PSM) estimator based on neighborhood characteristics. This type of nonparametric matching procedure attempts to limit analysis to only South Line neighborhoods that are matched with other (non-South Line) neighborhoods based on similar characteristics in 2000.

Given the variety of PSM models estimated in the literature, we describe our application here. The premise behind a PSM model is to first estimate the probability of becoming a LRT neighborhood prior to the announcement of the first alignment of LRT. Therefore, we estimate a probit model using neighborhood statistical areas as the unit of analysis and an indicator for a neighborhood being located within 1 mile of the South Line. We estimate this indicator based on neighborhood variables given in Table 1 to highlight the existing neighborhood conditions at the time of the announcement of the South Line in 2000. After the model is estimated, fitted values are constructed for the probability of becoming a LRT neighborhood. As suggested in Dehejia and Wahba (2002), we ensure that two necessary conditions for the implementation of PSM are satisfied. First, we ensure that the estimated propensity scores are balanced, which entails that no covariates or estimated propensity scores are significantly different from each other within a given propensity score strata.[39] Second, we impose a common support assumption so that any neighborhood that is outside the range of possible propensity scores for either treatment or control groups is removed from PSM. Finally, we formally match with replacement each South Line neighborhood with a control neighborhood based on nearest neighbor propensity scores. We allow each South Line neighbor to be matched with up to five control neighborhoods as long as no difference in propensity score between treatment and control neighborhood exceeds 0.05. In regressions, we weight by how often a neighborhood is matched with a South Line neighborhood in order to account for neighborhoods that were high quality matches with multiple South Line neighborhoods.[40]

Beyond alternative control groups, we test the sensitivity of results to Walk-N-Ride designated LRT stations and only new constructed residential units. Walk-N-Ride LRT stations are defined by the city and contain existing development density to support non-parking usage of the LRT station. Approximately 1/3 of the LRT stations along all three corridors is or would be designated as Walk-N-Ride. Since new housing units[41] may engender different impacts and represent a unique housing submarket, we examine if capitalization of LRT varies for this type of property.

[38] The limited number of observations for commercial properties prevents repeat sales hedonic regressions or analysis of subsets of earlier hedonic models.

[39] psscore in Stata 10.0 allows one to test this formally and we based our results on strata of propensity score width 0.1.

[40] Further details and formal tests of the 2 necessary conditions for PSM are available upon request.

[41] We consider a home to be new if it was constructed within 3 years of its transacted sales date.

Table 7
Robustness of results — condominiums.

Coefficient of interest	NE and SE control corridors		NE control corridor		PSM control neighborhoods		Walk-N-Ride		New properties
	Hedonic	Repeat sales	Hedonic	Repeat sales	Hedonic	Repeat sales	Hedonic	Repeat sales	Hedonic
	1 mile	1 mile	1 mile	1 mile	1 mile	1 mile	1 mile	1 mile	1 mile
Neighborhood effects									
LRTAnn∗SouthLine	0.1069**	0.0232	0.1481***	0.0185	0.0863***	0.0153	0.2637***	0.0963**	−0.0306
	(0.0431)	(0.0192)	(0.0517)	(0.0237)	(0.0198)	(0.0186)	(0.0530)	(0.0375)	(0.0659)
Neighborhood effects by time groups									
LRTAnn-2002∗SouthLine	0.0663	0.0040	0.0897	0.0150	0.0678***	0.0089	0.1557***	−0.0120	−0.0149
	(0.0422)	(0.0252)	(0.0601)	(0.0291)	(0.0254)	(0.0250)	(0.0519)	(0.0431)	(0.0802)
Year2003–2008∗SouthLine	0.1183***	0.0075	0.1587***	−0.0173	0.0943***	0.0027	0.2769***	0.0201	−0.0241
	(0.0428)	(0.0211)	(0.0501)	(0.0244)	(0.0201)	(0.0208)	(0.0483)	(0.0358)	(0.0776)
Observations	6547	3847	4289	2549	6129	4067	4817	2591	2970
Price gradient effects (1)									
LRTAnn∗DistLRT	−0.1510	0.0344	−0.1510	0.0344	−0.1510	0.0344	0.1154	0.0908	−0.3228**
	(0.1302)	(0.0340)	(0.1302)	(0.0340)	(0.1302)	(0.0340)	(0.0700)	(0.0683)	(0.1389)
Observations	2487	1376	2487	1376	2487	1376	1835	670	1319

Dependent variable = ln(Sales price) for hedonic specifications and ln(Sales price (t)) − ln(Sales price (t − 1)) in repeat sales specifications.
Results indicate separate regressions for the three sets of regressions indicated by italicized row headings. Each column indicates the data subset used for corresponding results. All hedonic regressions incorporate the same variables from estimated models in Table 4 and column 1 restates results from Table 4.
Repeat Sales regressions also include previous price deciles and a indicator for properties that include more than two sales.
Propensity Score Matching (PSM) Models are based on the five nearest neighbors within a propensity score of 0.05.
Control neighborhood observations are weighted by the frequency upon which they are matched with South Line neighborhood observations.
(1) Price gradient estimates are unchanged across the three sets of control groups because LRTAnn∗DistLRT is only estimated on South Line neighborhoods.
*** $p<0.01$.
** $p<0.05$.

8.1. Single-family additional results

We find positive neighborhood coefficients across models with statistical significance at the 5% level in all but three models given in Table 6. Results seem to support an overall positive impact with some heterogeneity due to control neighborhood definition and Walk-N-Ride versus Park-N-Ride LRT station neighborhoods. Using the Halvorsen and Palmquist (1980) correction,[42] the significant hedonic estimates generate impacts between 4.0% and 10.6%, which translates to between $8272 and $21, 921 for the average treatment single-family property sale of $206, 798. Estimated repeat sales coefficients indicate that single-family properties located in neighborhoods that added LRT experienced 4.6% higher appreciation rates for repeat sales within 1 mile of LRT stations and this result was similar across alternatively defined control groups. Given the average appreciation rate of 35.2% and base price of $157, 110 for South Line repeat sales properties, results provide an impact of approximately $2528 for 1 mile neighborhoods using the Northeast and Southeast control corridors. The smaller impacts for repeat sales estimates may be a result of using a sample of older homes in order to capture multiple housing transactions. If homebuyers place a premium on newer housing units or if LRT neighborhoods encourage the construction of housing units, then repeat sales estimates would understate estimated impacts. Results indicate no price premium for new SF housing units in LRT neighborhoods.

Results indicate an impact of 10.6% for the subset of properties near Walk-N-Ride LRT stations. One would expect that properties near Walk-N-Ride LRT stations would have large benefits from access and usage of LRT stations because of the absence of trip costs from driving and parking at LRT stations. Additionally, the positive neighborhood impact for Walk-N-Ride neighborhoods only in standard hedonic estimates is consistent with the presence of new transit-oriented development around the denser, more urban Walk-N-Ride neighborhoods. Comparing neighborhood estimates across hedonic and repeat sales specifications indicates a range of impacts from $2361 to $21, 921 or 1.1% to 10.6% for the average single-family house sold in the South corridor. Effects for the time periods after LRT announcement are consistent across specifications and indicate a positive effect after 2002 and almost no or sometimes even a negative effect in 2001 to 2002. The distance effect is insignificant across all specifications. The absence of a significant price gradient change from a LRT station in the presence of a positive and significant neighborhood effect highlights the concern that simply estimating price gradients may understate the impacts of LRT or any other changes in access (dis)amenities such as parks, airports or landfills.

8.2. Condominium additional results

Results for condominiums generate positive neighborhood impacts across models with significance limited to hedonic models and Walk-N-Ride neighborhoods. The hedonic estimates generate a range of impacts between 9.0% and 30.2%, which translates to between $18, 446 and $61, 899 for the average treatment neighborhood property sale of $204, 964. The large standard hedonic estimates can partially be attributed to the fact that this method cannot maintain a constant stock of housing units and captures impacts due to the inclusion of newer condominiums with unobserved higher valued structural characteristics such as more modern kitchens and open floor plans as well as the associated infrastructure development in and around new condominium complexes. Estimated repeat sales coefficients indicate that condominiums located in neighborhoods that added LRT experienced no significantly higher appreciation rate for repeat sales within 1 mile of LRT stations, but had 10.1% higher appreciation rates for repeat sales in Walk-N-Ride neighborhoods compared to properties located in areas that did not. The estimates of price gradients are insignificant in most specifications.

The lack of impacts for repeat sales estimates across most specifications may be due to new residential development in LRT station neighborhoods.[43] These new developments are not represented in repeat sales hedonic estimation because of the lack of multiple sales. Testing for price capitalization in the final column of Table 7 indicates no neighborhood impacts of LRT on new properties. We do find a negative

[42] This is determined by $e^{\theta} - 1$.

[43] Fig. 5 suggests the presence of greater new condominium construction after the announcement of LRT in South Line neighborhoods.

price gradient change for new condominiums, which may indicate a positive impact on new condominiums proximate to LRT stations. This premium does not appear to hold overall for the neighborhood.

Effects for the time periods after LRT announcement are similar to earlier results, with positive effects across both time periods for standard hedonics and almost no significant estimates for the initial time period in hedonic models as well as the two time periods in repeat sales estimates. Across all models, the magnitude of time period coefficients is larger after 2002, but we do find some positive impacts immediately after the announcement of LRT for Walk-N-Ride neighborhoods.

9. Conclusions

What do these results mean? The sensitivity of impacts across specifications indicates that a range of estimated impacts is more appropriate for any analysis. Also, results are heterogenous by property types, proximity to LRT stations, as well as repeat sales versus non-repeat sales properties. One can compute aggregate benefits from the positive estimates of neighborhood impacts. For all parcels within 1 mile of a LRT station, there were approximately 4790 single-family homes and 2487 condominiums. Given the range of estimated impacts for single-family homes, this corresponds to an aggregate benefit of between \$10.9 million and \$105.0 million. For condominiums, the estimated aggregate benefit ranges from \$45.9 million to \$153.9. The preferred estimate based on the full neighborhood sample and thus representative of the mean property values and type generate estimated benefits of \$39.6 million for single-family homes and \$57.6 million for condominiums. Insignificant estimated impacts of price gradients simplify the total estimated impacts to only these neighborhood impacts.

Our preferred estimates indicate a neighborhood benefit of \$97.2 million due to LRT in Charlotte. This is considerably lower than the \$450 million in LRT construction costs incurred in building the South Line. Of course, the full benefits of new development (residential and commercial) along LRT corridors is not captured in these estimates and may only materialize later after LRT operations have continued for a number years. Additionally, citywide benefits in reduced traffic congestion and other non-amenity impacts (pollution reduction, LRT related employer attraction, etc.) are excluded from our estimates.[44] Our research highlights two main conclusions. First, methods for estimating the effects of changes in proximity based amenities such as LRT, parks or even nuisances such as landfills need to estimate changes in both neighborhood property values as well as price gradients. Second, cities may be using public investment in LRT to target neighborhoods for residential and commercial redevelopment. This effect may even outweigh any potential benefits of LRT as a transportation improvement in cities with lower density land-use such as Charlotte, NC.

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References

Akaike, H., 1973. Maximum likelihood identification of Gaussian autoregressive moving average models. Biometrika 60 (2), 255–265.
American Public Transportation Association, 2009. Public Transit Ridership Report. Second Quarter, 2009.
Bailey, M.J., Muth, R.F., Nourse, H.O., 1963. A regression method for real estate price index construction. Journal of the American Statistical Association 58 (304), 933–942.
Baum-Snow, N., Kahn, M., 2005. Effects of urban rail transit expansions: evidence from sixteen cities. 1970–2000, *Brookings-Wharton Papers on Urban Affairs*, pp. 147–206.
Billings, S., Thibodeau, T.G., 2011. Intrametropolitan decentralization: is government structure capitalized in residential property values? Real Estate Finance and Economics 42 (4).
Boarnet, M., Compin, N., 1999. Transit-oriented development in San Diego County — the incremental implementation of a planning idea. Journal of the American Planning Association 65 (1), 80–95.
Bowes, D.R., Ihlanfeldt, K.R., 2001. Identifying the impacts of rail transit stations on residential property values. Journal of Urban Economics 50 (1), 1–25.
Calhoun, C.A., 1996. OFHEO house price indexes: HPI technical description. Office of Federal Housing Enterprise Oversight Technical Report.
Case, B., Quigley, J.M., 1991. The dynamics of real estate prices. The Review of Economics and Statistics 73 (1), 50–58.
Case, K.E., Shiller, R.J., 1987. Prices of single-family homes since 1970: new indexes for four cities. *New England Economic Review* September/October, pp. 45–56.
Case, K.E., Shiller, R.J., 1989. The efficiency of the market for single-family homes. The American Economic Review 1, 125–137.
Cervero, R., Landis, J., 1993. Assessing the impacts of urban rail transit on local real estate market using quasi-experimental comparisons. Transportation Research Part A: Policy and Practice 27, 13–22.
Cervero, R., Murphy, S., Ferrell, C., Goguts, N., Tsai, Y., Arrington, G., 2004. Transit-oriented development in the United States : experiences, challenges, and prospects. CI CRP Report 102. Transit Cooperative Research Program, Washington, DC.
Charlotte Area Transit System, 2009. http://www.charmeck.org/Departments/CATS 2009 Accessed 5/1/09.
Charlotte-Mecklenburg Planning Commission, 2001. 2025 Integrated Transit Land Use Plan.
Chen, H., Rufolo, A., Dueker, K.J., 1998. Measuring the impact of light rail systems on single-family home prices: a hedonic approach with GIS applications. Presented at Transportation Research Board, 77th Annual Meeting.
Clapp, J.M., Giaccotto, C., 1998. Price indices based on the hedonic repeat-sales method: application to the housing market. Journal of Real Estate Finance and Economics 16 (1), 5–26.
Debrezion, G., Pels, E., Rietveld, P., 2007. The impact of railway stations on residential and commercial property value: a meta-analysis. Real Estate Finance and Economics 35 (2), 161–180.
Dehejia, R., Wahba, S., 2002. Propensity score-matching methods for nonexperimental causal studies. Review of Economics and Statistics 84 (1), 151–161.
Dueker, K.J., Bianco, M.J., 1999. Light rail transit impacts in Portland: the first ten years. Presented at Transportation Research Board, 78th Annual Meeting.
Duncan, M., 2008. Comparing rail transit capitalization benefits for single-family and condominium units in San Diego, CA. Transportation Research Record, vol. 2067, pp. 120–130.
Gatzlaff, D.H., Smith, M.T., 1993. The impact of the Miami Metrorail on the value of residences near station locations. Land Economics 1, 54–66.
Gibbons, S., Machin, S., 2005. Valuing rail access using transport innovations. Journal of Urban Economics 57 (1), 148–169.
Goetzmann, W.N., Spiegel, M., 1995. Non-temporal components of residential real estate appreciation. Review of Economics and Statistics 1, 199–206.
Halvorsen, R., Palmquist, R., 1980. The interpretation of dummy variables in semilogarithmic equations. American Economic Review 3, 474–475.
Handy, S., 2005. Smart growth and the transportation-land use connection: what does the research tell us? International Regional Science Review 28 (146).
Hess, D.B., Almeida, T.M., 2007. Impact of proximity to light rail rapid transit on station-area property values in Buffalo, New York. Urban Studies 44 (5–6), 1041–1068.
Hill, R.C., Knight, J.K., Sirmans, C.F., 1997. Estimating capital asset price indexes. The Review of Economics and Statistics 2, 226–233.
Ihlanfeldt, K., 2003. Rail transit and neighborhood crime: the case of Atlanta, Georgia. Southern Economic Journal 70 (2), 273–294.
Kahn, M.E., 2007. Gentrification trends in new transit-oriented communities: evidence from 14 cities that expanded and built rail transit systems. Real Estate Economics 35 (2), 155–182.
Kilpatrick, J.A., Throupe, R.L., Carruthers, J.I., Krause, A., 2007. The impact of transit corridors on residential property values. Journal of Real Estate Research 29, 303–320.
McDonald, J.F., Osuji, C.I., 1995. The effect of anticipated transportation improvement on residential land values. Regional Science and Urban Economics 25, 261–278.
McMillen, D.P., McDonald, J., 2004. Reaction of house prices to a new rapid transit line: Chicago's Midway line, 1983–1999. Real Estate Economics 32 (3), 463–486.
Messina, D., 2008. Light Rail's Success Outshines Woes, Charlotte Exec Says. Virginian-Pilot.
O'Sullivan, S., Morrall, J., 1996. Walking distances to and from Light-Rail Transit Stations. Transportation Research Board 1538, 19–26.
Quigley, J.M., 1995. A simple hybrid model for estimating real estate price indexes. Journal of Housing Economics 4 (1), 1–12.
Redfearn, C.L., 2009. How informative are average effects? Hedonic regression and amenity capitalization in complex urban housing markets. Regional Science and Urban Economics 39 (3), 297–306.
U.S. Census, 2007. American Community Survey — Mecklenburg County, NC. http://www.factfinder.census.gov. Accessed 5/1/10.

[44] It is important to note that estimated impacts are capturing the effect of both greater demands for properties in LRT neighborhoods as well as decreased property values in control neighborhoods. Therefore, estimated impacts may vary if the increase in LRT property values is due to new city residents or the relocation of existing city residents.