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Is the light rail “Tide” lifting property values? Evidence from Hampton Roads, VA☆

Gary A. Wagner[a], Timothy Komarek[b,*], Julia Martin[b]

[a] Federal Reserve Bank of Cleveland, 150 E. 4th St, Cincinnati, OH 45202, USA
[b] Department of Economics, Old Dominion University, Norfolk, VA 23529, USA

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ABSTRACT

In this paper we examine the effect of light rail transit on the residential real estate market in Hampton Roads, Virginia. Norfolk's Tide light rail began operations in August of 2011 and has experienced disappointing levels of ridership compared to other light rail systems. We estimate the effect of the Tide using a difference-in-differences model and consider several outcome variables for the residential housing market, including sale price, sale-list price spread and the time-on-market. Our identification strategy exploits a proposed rail line in neighboring Virginia Beach, Virginia that was rejected by a referendum in 1999. Overall, the results show negative consequences from the constructed light rail line. Properties within 1500 meters experienced a decline in sale price of nearly 8%, while the sale-list price spread declined by approximately 2%. Our results highlight the potential negative effects of light rail when potential accessibility benefits do not out weigh apparent local costs.

1. Introduction

Rail transit systems have become an increasingly popular transportation alternative in many U.S. metropolitan areas. Public funds are often used not only to finance construction, but also to subsidize operating costs. A Brookings Institution report on transportation infrastructure shows that 31 large metro systems operated at a loss in 2013 (Kearney et al., 2015). Further, systems with fewer total passengers tended to lose more money per passenger ride than their more heavily used counterparts. Cities often justify the use of public funds by citing the benefits of commuter rail transit systems. Benefits often include reducing traffic congestion and emissions, increasing accessibility to jobs and amenities, providing an affordable and sustainable mode of transport, and spurring economic activity (Mohammad et al., 2013). Nonetheless, there are also potential negative externalities associated with light rail, such as crime, noise, safety and parking issues (Bowes and Ihlanfeldt, 2001). The degree of public financing along with the purported local economic benefits and potential negative externalities make measuring the local effect of rail transit an important consideration for policy makers and communities.

A popular strategy for measuring the effect of rail transit projects on local residents is examining the capitalization of stations on nearby home values. Researchers often argue that the main benefit due to rail transit stations comes from increased access to regional amenities such as central business districts, education centers, entertainment and recreation venues, etc. In this light, land and housing markets should adjust to account for the benefits of increased accessibility. However, current and future residents near stations could also consider the potential negative externalities of light rail when buying and selling a residential property. There is a large literature measuring the effect rail transit on various measures of the residential and commercial real estate market. The results have been mixed with studies suggesting a positive effect and others questioning the benefits (Debrezion et al., 2007). Mohammad et al. (2013) provide the distribution of the estimated land and property value changes due to light rail from 1991-2008. The average effect was found to be 8% with a standard deviation of 17%, while fewer than 5% of the 102 estimates examined in the study indicated a negative effect on prices. Billings (2011) suggests that the variation in estimated impacts could be due to the use of inadequate control groups. Similarly, Parmeter and Pope (2013) argues for leveraging quasi-experimental estimation techniques when estimating hedonic pricing models. Several studies have used credible identification strategies and have aided in further shedding light on the policy debate surrounding the effect of rail transit on real estate values.

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* Corresponding author.
E-mail addresses: gary.wagner@clev.frb.org (G.A. Wagner), tkomarek@odu.edu (T. Komarek), juliammartin52@gmail.com (J. Martin).

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For example, Gatzlaff and Smith (1993) in Miami, McMillen and McDonald (2004) in Chicago, and Hurst and West (2014) in Minneapolis considered areas outside of a pre-determined threshold as the control group. Gibbons and Machin (2005) and Dubée et al. (2013) used the opening of new stations and service frequency for long-standing rail transit lines in London and Montreal. Alternatively, Billings (2011) exploited a proposed rail corridor to examine a newly constructed light rail system in Charlotte. Each of these studies took place in large metro areas with populations over 2 million residents and ridership figures exceeding 3 million passenger trips per year.[1] The ridership per capita for these metro areas were all above 2 trips per resident per year with Montreal having over 77 trips per resident in 2013. Thus, the quasi-experimental literature has focused on successful light rail systems, at least in terms of ridership, in large metro areas.

In this paper, we estimate the effect of Norfolk, Virginia's light rail system, named the Tide, on the residential housing market. Our estimates use data from a multiple listing service (MLS) for southeast Virginia and consider three housing outcomes: sale price, sale-list price spread, and time-on-market. Our identification strategy uses a difference-in-difference hedonic model for the Tide, which began construction in 2007 and opened in 2011. We exploit proposed station locations in neighboring Virginia Beach, Virginia as the control group. Voters in Virginia Beach rejected a referendum for a proposed light rail line in 1999. Our estimated results show the Tide light rail negatively effected the local residential real estate market. In particular, homes within 1500 meters of a constructed station sold for approximately 8% less than similar homes in the control group. This resulted in an approximately $75 million aggregate reduction in housing values due to the light rail.[2] Homes near constructed stations also sold for a lower amount versus the original list price (the sale-list price spread) compared to the control group. However, we do not find evidence that the time-on-market for homes near constructed light rail stations differ from those near proposed stations.

The paper contributes to the literature in several ways. First, we are the first paper to use a quasi-experimental identification strategy that finds a negative effect from light rail on residential real estate prices. Our identification strategy, by considering areas along a proposed route that was not ultimately developed as the control group, is similar to that used by Billings (2011) in Charlotte. Our paper as well as Billings (2011) examine nascent light rail lines in a city. In contrast to the previous literature, we are able to trace out the dynamic effect of light rail construction and operations on the local housing market. We show that for the Norfolk Tide there is a differential effect between the construction and operations phases for each of our outcome variables.

Second, in addition to sale price, we also examine several outcome variables that are often neglected in the academic literature on transit related economic development such as time-on-market and the sale-list price spread. To accomplish this we leverage information in our data that provides details on a wide-variety of status changes for every property listing, including re-listings and original listing prices. Time-on-market is a metric that is often used by real estate professionals, and provides a measure of the liquidity of a property (Krainer, 2001; Knight, 2002). Thus, we are able to measure if the real estate market around light rail stations is “hotter” or “colder” than the control group. Furthermore, we examine the effect of the light rail construction and operations on the sale-list price spread. The original list price represents the sellers perceived value of a home based on observed and unobserved housing and neighborhood characteristics. Thus, the sale-list price spread provides a measure of the disconnect between how buyers and sellers perceive the light rail. This notion has been examined in the housing foreclosure literature (e.g. Campbell et al. (2011)), however, to the best of our knowledge it has not been considered in quasi-experimental studies of transportation improvement.

Finally, we focus on a light rail transit system, the Norfolk Tide, that has struggled financially as well as with low ridership compared to similar sized metro areas. Kearney et al. (2015) shows that the Norfolk Tide light rail had the lowest number of passenger trips in 2013 of the light rail systems examined in the U.S. In comparison, Buffalo and Salt Lake City, each with a similar population to the Virginia Beach-Norfolk metro area, had 3.5 and 10.7 times the ridership.[3] Odell (2016), in an editorial written for *The Wall Street Journal*, recently went so far to say “The Tide moves from places you don't work to areas you don't wish to visit.” The Tide was originally envisioned as a starter line that would be expanded in the future. However, with tight budgets and a tenuous political environment the expansion is unlikely to take place. Our results are useful as smaller metro areas continue to consider building new light rail infrastructure and to areas with potentially low ridership and low accessibility benefits.[4]

2. Background and literature review

In this paper, we examine several outcome variables related to residential real estate transactions and light rail transit in Hampton Roads, VA (sale price, time-on-market, and sale-list price spread). The economics literature has focused on real estate transaction prices. Therefore, we concentrate the theoretical considerations and literature review on light rail capitalization in the final sale price.

2.1. Overview and economic theory

Economic theory suggests that rail transit could have either a positive or negative effect on the residential housing market. In their original formulation, Alonso (1964) and Muth (1969) modeled the bid-rent for a property based on location. Holding utility levels constant across geographic space leads residential real estate prices to decline as the distance increases from a central business district. This prediction comes from the desire of residents to access jobs and amenities in the central business district. The academic literature on transit related economic development has focused on this notion of price capitalization from increased accessibility. Conversely, homes in a close proximity to rail transit could experience disamenity effects from a fear of increased crime (Phillips and Sandler, 2015), noise (Walker, 2016), congestion, and parking issues. There is a large economics literature on hedonic pricing models and environmental externalities (e.g. Boyle and Kiel, 2001). This literature highlights the NIMBY (Not in My Back Yard) sentiment for many types of externalities. There is some evidence of a similar NIMBY attitude for light rail transit stations (Atkinson-Palombo, 2010) as with other potential negative externalities.

There is a vast literature on the effect of rail transit on residential housing. Studies have analyzed a wide range of cities, types of rail systems, property types, and identification strategies.[5] Debrezion et al.

[1] The populations and ridership according to the Bureau of Economic Analysis, Statistics Canada, Eurostat and the American Public Transportation Association in 2013 were: Charlotte (2.34 million residents and 4.9 million trips), Minneapolis (3.46 million residents and 10.2 million trips), Montreal (3.99 million residents and 308.7 million trips), Miami (5.86 million residents and 22.8 million trips), Chicago (9.55 million residents and 278.2 million trips), and London (13.8 million residents).

[2] The aggregate reduction in home values due to the light rail construction and operations was calculated as the estimated average effect of the light rail * the average value of effected homes after construction began * total number of homes effected by the light rail (−7.8% * $234,800 * 4138).

[3] The light rail ridership numbers are provided by the Brookings Institution for 2013 and show 1.76million annual light rail trips on the Norfolk Tide, 6.3million annual trips on the Buffalo Metro Rail, and 18.9 million annual trips in Salt Lake City.

[4] See http://www.thetransportpolitic.com/under-consideration/planned-light-rail-systems/ for a list of light rail systems in the development stages.

[5] Previous studies have investigated the effects of rail systems in Atlanta, Buffalo, Calgary, Charlotte, Chicago, Dallas, London, Los Angeles, Manchester, Miami, New York, Philadelphia, Portland, Sacramento, St. Louis, San Diego, San Francisco, San Jose, Santa Clara, Seoul, Taipei, and Washington D.C.

Table 1
Summary of New Light Rail Transit Since 2003.

	Charlotte	Houston	Minneapolis	Norfolk	Phoenix	Seattle/Tacoma
Original Open Date	2007	2004	2004	2011	2008	2003*
Length of lines in 2013 (in miles)	9.6	12.8	12	7.4	20	21.95
Fares in 2013 (in dollars)	4,358,896	4,483,444	9,808,579	687,892	12,791,801	14,845,952
Operating Expense in 2013 (in dollars)	13,084,582	18,385,544	32,424,866	12,374,424	28,711,628	52,903,983
Unlinked Passenger Trips 2013	4,919,307	11,320,995	10,162,919	1,762,284	14,286,093	9,730,027
Loss per Passenger Trip (dollars)	−1.77	−1.23	−2.23	−6.63	−1.11	−3.91
Passenger Trips per Job 2013	3.6	2.9	4.3	1.7	6.0	4.2
Population Density	742.3	629.4	543.8	438.0	301.4	572.6
Travel Time Index 2000	1.2	1.23	1.27	1.17	1.25	1.33

Note: The length of line(s) data come from The Transport Politic (http://www.thetransportpolitic.com/databook/), 2013 fares, operating expenses and unlinked passenger trips are from the Brookings Institution. The Travel Time Index data is from the Texas A & M Transportation Institute. Jobs and the Travel Time Index are for the Metropolitan Statistical Area. The Tacoma Line opened in 2003 while the longer Central Line through Seattle opened in 2009.

(2007) and Mohammad et al. (2013) provide reviews and meta-analyses of the early empirical literature. Both meta-analyses use general measures of accessibility to explain the variation in sale price. In particular, Debrezion et al. (2007) uses sales within 0.25 miles and 250 meters, and Mohammad et al. (2013) uses dummy variables for different distance thresholds up to 805 meters. These accessibility measures, while useful, do not allow for comparison of the actual ridership across studies (and subsequently cities). Thus, the recent meta-analyses do not provide any evidence on whether the success of a light rail system, insofar as ridership implies success, effects the local real estate market. It seems reasonable to expect a light rail system that provides accessibility benefits to also have significant ridership. Zhong and Li (2016) suggests that heterogeneity across cities in terms of technology, development stage and housing markets could explain differences in property values. Furthermore, Baum-Snow and Kahn (2005) argue that new rail transit is most effective in more densely populated areas and in locations with elevated commuting times. In this light, Table 1 shows that cities have heterogeneous experiences after constructing new light rail transit. It depicts the length of the rail line, finances and measures of ridership for cities that have constructed new light rail transit systems since the mid 2000s. These metro areas with newly constructed light rail lines are useful for comparison. They have similar sized populations, between 1 million and 4 million, yet experienced large differences in finances and ridership. All of the cities lost money on each passenger trip in 2013. However, the Tide in Norfolk lost almost twice as much per passenger as the other light rails. The Tide also had the lowest level of passenger trips per job and is in a metro area with the second lowest population density. The Travel Time Index for 2000 shows level of traffic congestion prior to any of the cities constructing a light rail system. Norfolk's measure of 1.17, the lowest of any of the metro areas, indicates that on average travelers should expect a typical trip across town to be 17% longer during peak congestion compared to free-flow conditions. In general, the information in Table 1 suggests the Tide had less favorable local characteristics prior to construction and has also been less successful than its counterparts in terms of finance and ridership.

2.2. Quasi-experimental design literature

The early work often utilized traditional hedonic pricing models and relied on cross-sectional variation to measure the effect of rail transit on housing. Parmeter and Pope (2013) argue that the traditional hedonic model often fails to uncover causal relationships due to omitted variable issues. Instead, they advocate for quasi-experimental techniques for conducting hedonic property valuation. In a similar vein, Billings (2011) argues that the heterogeneity in estimated rail transit impacts could be due to studies using inadequate control groups.

In this light, we provide a brief review of the quasi-experimental literature on rail transit and the housing market. The difference-in-differences model is the most popular quasi-experimental technique employed. To identify the effect of a rail transit system researchers use a treatment and control comparison before and after construction or opening. However, there are differences in how the studies determine an appropriate control group.

The most popular identification strategy uses distance measures from rail transit stations compared to neighborhoods or areas just outside of a pre-determined cutoff from a station (e.g. 1000 m). Gatzlaff and Smith (1993) use repeated residential sales data to construct price indices for residential properties in Miami near transit stations compared to areas further away. They find modest evidence of capitalization from rail transit. McMillen and McDonald (2004) employ a similar technique along with using hedonic regression models. Their results show positive anticipation effects of the Midway Line in Chicago and suggest that home values appreciated around 7% compared to homes farther from the nearest transit station. Hurst and West (2014) look at land use changes in Minneapolis using parcel level data. They compare parcels within 0.5 miles of a station to parcels greater than 0.5 miles away. The results suggest that the rail stations induce land use changes for single-family residential parcels.

Several studies supplement a distance-based threshold strategy for determining the control group with service changes for some residents on established rail lines. Gibbons and Machin (2005) use a 2-kilometer cutoff along with new station construction and an increase in the frequency of service (trains per hour) that effect some residents in London. Dubée et al. (2013) undertakes a similar strategy for changes in station access and the number of daily trips for a transit line traveling into Montreal. Both studies examine heavily traveled rail transit systems and show positive premiums from the increased station access and service frequency.

There are several concerns with using properties outside of a distance threshold as the control group. First, the distance cutoffs are often arbitrary. This concern can be alleviated with sufficient sensitivity analysis for a range of cutoff distances. Secondly, the placement of stations may be in more desirable locations. Thus, it is important to show that the treatment locations were not in neighborhoods appreciating at a faster rate than the control neighborhoods further from the stations. This may be problematic in cities that place rail transit around major business centers, such that the type of properties further from stations are quite different than those around actual stations.

Several studies propose alternative control groups that are not based on a distance threshold from constructed transit stations. Dueker and Bianco (1999) study the light rail system in Portland by using a bus line as the control group. One of their outcome measures considers residential development and the results suggest a positive relationship with the light rail system. Billings (2011) examines the light rail system in Charlotte. The author uses a proposed corridor that was not ultimately selected as the first rail line for the control group. He examines the effect on sales prices for single family, condominiums and commercial properties by comparing properties within one mile of the constructed line and the same distance around the proposed corridor. The results suggest residential homes (single family and condominiums) appreciate in value by 6.9% during construction, but commercial properties remained unaffected.

2.3. Light rail in hampton roads, virginia

Hampton Roads, a metropolitan area made up of 16 independent cities and counties in southeast Virginia, has a long history of use and interest in commuter rail transit.[6] In the late 1990s the region considered a light rail project that would have connected a major tourist destination, the oceanfront in Virginia Beach, with the business center of the region in downtown Norfolk. The proposed line would have been partially built along a preexisting commercial rail corridor. In November 1999, residents from Virginia Beach rejected a referendum (55 percent to 45 percent vote) for the City Council to adopt an ordinance to approve the development and finance of the Tide.[7] Nonetheless, the original proposed line through Norfolk and Virginia Beach was outlined in the final environmental impact statement submitted by the region's transit agency, Tidewater Transportation District Commission, to the U.S. Department of Transportation in 2000.[8]

Following the rejection of the proposed system, Norfolk ultimately constructed a light rail transit system confined within its city borders. Construction on the Tide began in December 2007 and the line ultimately opened for service in August 2011. The 7.4 mile route has 11 stations that include access to a large medical park, downtown Norfolk, a minor league baseball stadium, and Norfolk State University.[9] Fig. 1 shows the constructed Tide light rail stations and line along with the original plan that included 13 stations ranging from Norfolk's downtown (and central business district) in the west to Virginia Beach's oceanfront area in the east. In Fig. 1, the (original) proposed stations are depicted as diamonds while the actual constructed stations are shown as circles. For reference purposes, the actual stations are labeled numerically from west to east with the prefix “A” and the proposed stations are labeled with the prefix “P”. The actual light rail line is depicted as a black line in Fig. 1 that ends at the Newtown Road station (A11 on Fig. 1) that defines the border between Norfolk and Virginia Beach.

The original construction costs for the project totaled $232 million, however due to construction problems and over a year and a half of delays the final cost tallied $338 million.[10] As shown in Table 1, the Tide had approximately 1.7 million passenger trips in 2013 with fare revenue equal to $687,892. This was well below operating costs of $12,374,424, making the Tide the worst performing light rail system of the 31 studied by Brookings in terms of finances and ridership.

3. Empirical model

To measure the effect of the Tide light rail on residential real estate we use a hedonic model. Our identification strategy builds off the previous light rail literature by exploiting a quasi-experimental approach.[11] In particular, we use a difference-in-differences model to aid in overcoming issues with omitted variable bias that often plague traditional hedonic models. For example, the traditional hedonic model would be biased if light rail stations were located in more (or less) expensive housing areas due to unobserved factors. Our analysis begins with the following difference-in-differences empirical model:[12]

$$Y_{ijt} = \beta(D_t{*}LRT_{ijt}) + X_i\theta + Neighborhood_j\psi + YearMonth_t\phi + \epsilon_{ijt} \quad (1)$$

where Y_{ijt} is an outcome variable (the log real sale price, sale-list price spread, and time-on-market) of each house i in neighborhood j at time t.[13] X_i is a vector of the housing characteristics for house i. Our data provides a wide range of housing characteristics that include the home's school district, 5 types of ownership and financing, 22 categories of architectural style, 12 interior features, 18 exterior features, among other relevant attributes. $Neighborhood_j$ is a vector of census block group fixed effects to account for time-invariant neighborhood effects such as urban and natural amenities, among others. $YearMonth_t$ is a vector of year-by-month dummy variables. The time fixed effects control for temporal changes that effect all homes such as seasonality and the local business cycle. The time fixed effects along with controls for the type of home construction and financing (e.g. REO, short sale and new construction) help mitigate issues from the housing collapse during the Great Recession.[14]

An important aspect of the difference-in-differences strategy is choosing an appropriate control group. In Section 2 we described the different types of control groups used in the literature. Our preferred strategy follows Billings (2011) by using a proposed rail line that was not ultimately constructed. The proposed station locations on this line provide a useful counterfactual group for the constructed Tide light rail stations. We focus on homes within 1500 meters of a constructed or proposed station. Since several of the proposed stations ultimately overlapped with actual stations, we limit our control group to proposed stations P7 through P13 in Fig. 1. Proposed station P6 is omitted from the control group because the 1500 meter perimeter around that station overlaps with the 1500 meter perimeter around actual station A11. Moreover, both the proposed and constructed lines traveled along an abandoned portion of the Norfolk Southern Corporation right-of-way. This route was at least partially chosen because of financial and planning benefits of using the pre-existing rail right-of-way. Furthermore, we also show the robustness of our results by providing estimates using a distance-based cutoff from the actual rail stations.

The goal of Eq. (1) is to provide a clear examination of the effect of the light rail transit system on the residential real estate market. The

[6] For instance, the 2010 Hampton Roads State of the Region Report published by the Center for Economic Analysis and Policy at Old Dominion University indicates that the region used electric trolley cars for public transit in the early 20th century. The Hampton Roads region is formally the Virginia Beach-Norfolk-Newport News metropolitan statistical area.

[7] The specific referendum read as follows: “Should the City Council adopt an ordinance approving the development and financing of the proposed Virginia Beach-Norfolk- Naval Base-Light Rail transit project?”

[8] The final environmental impact statement report is available on the region's current transit agency's website, Hampton Roads Transit (HRT): http://gohrt.com/vbtes/norfolk-va-beach-feis.pdf.

[9] There are approximately 7000 students enrolled at Norfolk State University, while the medical park includes Sentara Norfolk General Hospital, Children's Hospital of the King's Daughter and Eastern Virginia Medical School. According to data from the Census Bureau's Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics (LODES), more than 28,000 jobs were located in the Census tract with Norfolk's downtown and medical complexes in 2014.

[10] http://gohrt.com/services/the-tide/funding-cost-to-complete.

[11] See Parmeter and Pope (2013) for a detailed discussion on quasi-experimental techniques with hedonic property valuation.

[12] This specification represents the generalized difference-in-difference model by including neighborhood fixed effects and year-by-month fixed effects.

[13] The sale-list price spread is the log difference between the final selling price and the original listing price for a property. The time-on-market is the number of days the property has been on the market up to the sale. Prices are adjusted to 2010 dollars using the Consumer Price Index (CPI).

[14] REO describes properties owned (and in our case being sold by) a lender, e.g. a bank or a government agency.

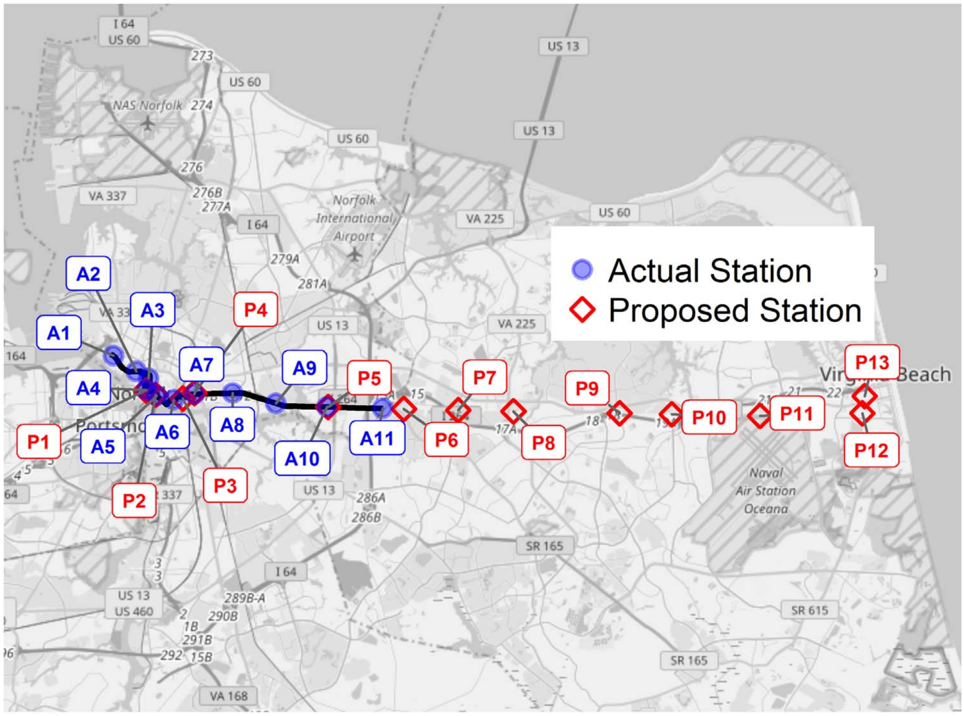

Fig. 1. Proposed and Actual Stations for the Tide.

variable of interest is (D_t*LRT_{ijt}), which interacts the treatment group indicator variable (*LRT*) with an indicator variable for the time period of interest. We specify D_t three different ways to examine potential differential effects between the total, construction, and operations periods. To capture the total effect, we set D_t equal to 1 between December 2007 and August 2016 and we refer to this period as the *construction & operations phases* in the empirical results. To isolate the construction and operations phases individually, we define the variable *construction phase* to equal unity between December 2007 and July 2011, while the variable *operations phase* equals unity from August 2011 to August 2016.

The parameter β represents the difference-in-difference estimator that compares the contemporaneous average effect for homes near the constructed light rail against the control group near a proposed station. In some specifications, we also split the *LRT* indicator into two separate indicators for homes within 800 meters (*within*800*m*) and homes between 800 and 1500 meters (*within*1500*m*) of an actual or proposed station to explore any potential differential effects for homes that are very close to stations.

The key identifying assumption of the difference-in-differences model is that the outcome variable (real sale price, sale-list price spread, and time-on-market) exhibit similar pre-existing trends (Angrist and Pischke, 2009). To test this assumption we also estimate the dynamic effect of the rail transit system. Estimating the dynamic model with numerous time periods lends itself to a test of causality in the spirit of Granger (1969). By conditioning on fixed effects the time-frame during the treatment (construction or operations of the light rail line) should predict the housing market outcome variables, while the leads before should not.

$$Y_{ijt} = \lambda_t LRT_{ijt} * Time_t + X_i\theta + Neighborhood_j\psi + YearMonth_t\phi + \epsilon_{ijt} \qquad (2)$$

Eq. (2) shows the dynamic model, where the control variables and fixed effect strategy are the same as Eq. (1). LRT_{ijt} indicates house i in neighborhood j at time t for the Tide light rail treatment group and $Time_t$ is a vector of half-year (6-month) time dummy variables. The coefficients λ_t show average differences between light rail and non-light rail properties relative to the base time period. Furthermore, by including data prior to the construction phase we measure anticipatory effects of the rail transit system, along with a direct test of the difference-in-difference's pre-existing trends assumption. We estimate each set of regressions with OLS and cluster the standard errors at the census block group.

4. Data

The real estate data come from the Real Estate Information Network (REIN) a southeast Virginia multiple listing service. It includes a number of structural housing characteristics for all homes listed for sale with a real estate agent within Norfolk and Virginia Beach, VA from July 2002 through August 2016. A complete data set of home listings and status changes allows us to accurately measure the time a home was on the market as well as the spread between the initial asking price and the final sale price. The structural housing attributes range from age, square footage and number of bathrooms to exterior features like the presence of a patio or a shed and whether or not the sale was a REO or short sale. A complete list of the housing characteristics can be found in Appendix A.

The data also include the postal address of each property, which we used to create longitude and latitude coordinates using GIS software. We used the geocoordinates to determine the census block group and distance of each property to the nearest constructed or proposed light rail station. In our primary analysis we focus on homes within 1500 meters of a station. We also use Google's MAP API to calculate the walking time from each property to the nearest station. Standard data cleaning for missing characteristics and outliers resulted in 17,120 observations within 1500 meters of a proposed or constructed light rail station.

Table 2 shows summary statistics for homes sold within 1500

Table 2
Summary Statistics.

	Treatment Group		Control Group			
	Mean	Standard Deviation	Mean	Standard Deviation	Difference in means	P-Value
Sale price (dollars)	239,516.400	148,233.900	227,755.500	136,529.600	11,760.900	0.000
Price spread	-0.067	0.176	-0.040	0.115	-0.027	0.000
Days on market	76.746	93.304	60.081	82.656	16.665	0.000
Distance to station (meters)	806.641	377.473	1002.240	346.984	-195.599	0.000
Walking time (in minutes)	14.083	7.771	20.330	8.193	-6.247	0.000
Age	53.578	33.150	36.061	17.730	17.517	0.000
Bedrooms	2.998	1.066	2.975	0.790	0.023	0.106
Full baths	1.839	0.687	1.857	0.593	-0.019	0.060
Half baths	0.468	0.533	0.547	0.510	-0.079	0.000
New home	0.120	0.325	0.123	0.329	-0.003	0.557
Off street parking	0.264	0.441	0.187	0.390	0.077	0.000
Pool	0.048	0.213	0.082	0.274	-0.034	0.000
REO	0.096	0.295	0.067	0.249	0.029	0.000
Short sale	0.028	0.166	0.034	0.182	-0.006	0.034
Sqft (in 1000s)	1.763	0.820	1.563	0.528	0.200	0.000
Waterfront	0.091	0.288	0.080	0.271	0.011	0.011

Notes: REO denotes properties owned (and in our case being sold by) a lender, e.g. a bank or a government agency. The treatment group contains 6716 homes sold within 1500 meters of an actual station, while the control group consists of 10,404 homes sold within 1500 meters of a proposed station. The full sample period includes all homes sold between July 2002 and August 2016.

meters of constructed or proposed light rail stations for the full sample period. We also show the difference in means between the treatment and control group and the accompanied p-value. There are 6716 sales within 1500 meters of actual stations and 10,404 sales within 1500 meters of a proposed station. The mean real sale price in the treatment group ($239,516) is higher than the control group ($227,744). Furthermore,the sale-list price spread and time-on-market are both also statistically different for properties near actual light rail stations compared to the control group at the 1% level. We provide summary statistics for selected housing characteristics in Table 2. For several of the observable characteristics (e.g. age, pool, square feet) the difference between the treatment and the control is statistically different from each other at the 1% level. Notably, there is a difference in whether or not a property was sold as an REO or short sale between the treatment and control group. The construction and operations of the Tide took place during the housing bust and recovery period that began in late 2007. The differences in observable housing characteristics noted in Table 2 between the treatment and control groups reinforces the need to include our wide range of housing characteristics in the empirical model to control for any observable systematic differences between properties. Our neighborhood fixed effects aid in controlling for any time invariant differences, while the time fixed effects are beneficial in controlling aggregate time-varying differences effecting the Hampton Roads, VA real estate market.

5. Empirical results

We begin by providing estimates of the difference-in-difference hedonic model shown in Eq. (1). The results are separated by the dependent variable (the log of real sale price, sale-list price spread, and time-on-market) used in the analysis. For each dependent variable we examine the overall neighborhood effect of light rail transit by comparing areas near constructed stations against proposed stations. In particular, we use distances between 800 and 1500 meters and within 800 meters of a station. We also examine the light rail distance gradient by using the walk time from each property to the nearest station. Billings (2011) argues that is useful to consider the total neighborhood effects as well as the distance gradient, because of potentially misleading results when examining either by itself.

5.1. Sale price

Table 3 shows difference-in-difference hedonic pricing estimates for properties within 1500 meters of a Tide light rail station or a proposed station. The difference-in-difference estimate is given by the coefficient β for the variable of interest from Eq. (1). Selected covariates are provided in the table with each variable having the correct expected sign. Each column considers a different distance measure or time-frame for the light rail system. Column (1) shows the cumulative effect of being within 1500 meters of a station starting at the beginning of construction phase (December 2007) and through the operating phase. Column (2) differentiates between the construction and operations phase. Both estimates show that the sale price declined in actual light rail neighborhoods relative to the control group. The average property depreciation from the start of construction and including the operation phase (Column 1) was 7.8%. Furthermore, the subsequent columns show that there is a differential impact during the construction and operations phase. The results suggest that home sales fell by 4.8% during construction, but by over 9% after the light rail began operations (column (2)). This result is consistent with columns (3) and (4), which separate out properties within 800 meters with those over 800 meters up to 1500 meters. These specifications show that properties closer to the light rail stations experienced a larger price depreciation than those further away, relative to the control group. For example, our estimates show a 10.7% decrease in the average sale price for homes within 800 meters of a station following the operations phase of the Tide.

In addition, the walk time gradient column (5) shows how the sale price changes as the walking distance from a station grows. The walk time gradient is also consistent with the total neighborhood effect. The estimated coefficient shows that the sale price increases the further away a property is from a station. These results provides some evidence that the disamenities due to being near a light rail station such as noise, potential crime, and other NIMBY issues seem to outweigh the accessibility benefits.

5.2. Price spread

Table 4 shows difference-in-difference results for the sale-list price

Table 3
Sale Price Results (control group=homes within 1500 m of proposed stations).

	(1) Log(Sale Price)	(2) Log(Sale Price)	(3) Log(Sale Price)	(4) Log(Sale Price)	(5) Log(Sale Price)
age	-0.0089***	-0.0088***	-0.0089***	-0.0089***	-0.0090***
	(0.0009)	(0.0009)	(0.0008)	(0.0008)	(0.0009)
agesq	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
sqft	0.6313***	0.6318***	0.6296***	0.6302***	0.6285***
	(0.0506)	(0.0506)	(0.0507)	(0.0508)	(0.0500)
sqftsq	-0.0629***	-0.0629***	-0.0626***	-0.0627***	-0.0625***
	(0.0097)	(0.0097)	(0.0097)	(0.0097)	(0.0095)
bedrooms	0.0034	0.0034	0.0038	0.0038	0.0038
	(0.0065)	(0.0065)	(0.0065)	(0.0065)	(0.0065)
full baths	0.0730***	0.0729***	0.0730***	0.0728***	0.0725***
	(0.0102)	(0.0102)	(0.0103)	(0.0103)	(0.0102)
half baths	0.0328***	0.0328***	0.0330***	0.0330***	0.0333***
	(0.0127)	(0.0127)	(0.0127)	(0.0128)	(0.0124)
waterfront	0.1493***	0.1499***	0.1482***	0.1488***	0.1477***
	(0.0200)	(0.0201)	(0.0199)	(0.0200)	(0.0198)
new home	0.0782***	0.0783***	0.0781***	0.0780***	0.0785***
	(0.0154)	(0.0156)	(0.0154)	(0.0156)	(0.0150)
pool	0.0268**	0.0280**	0.0264**	0.0276**	0.0249**
	(0.0129)	(0.0129)	(0.0128)	(0.0128)	(0.0124)
off street parking	-0.0034	-0.0035	-0.0034	-0.0034	-0.0031
	(0.0063)	(0.0063)	(0.0063)	(0.0063)	(0.0062)
reo	-0.2981***	-0.2979***	-0.2983***	-0.2982***	-0.3002***
	(0.0165)	(0.0164)	(0.0165)	(0.0164)	(0.0169)
short sale	-0.2003***	-0.2009***	-0.2010***	-0.2015***	-0.1985***
	(0.0146)	(0.0145)	(0.0146)	(0.0146)	(0.0145)
LRT	0.0567	0.0562			
	(0.0736)	(0.0742)			
LRT*(construction & operations phases)	-0.0788***				
	(0.0188)				
LRT*(construction phase)		-0.0486***			
		(0.0183)			
LRT*(operations phase)		-0.0976***			
		(0.0212)			
within800m			0.0246	0.0249	
			(0.0765)	(0.0770)	
within1500m			0.0529	0.0528	
			(0.0744)	(0.0750)	
within800m*(construction & operations phases)			-0.0869***		
			(0.0256)		
within1500m*(construction & operations phases)			-0.0707***		
			(0.0208)		
within800m*(construction phase)				-0.0530*	
				(0.0275)	
within1500m*(construction phase)				-0.0451**	
				(0.0184)	
within800m*(operations phase)				-0.1072***	
				(0.0263)	
within1500m*(operations phase)				-0.0874***	
				(0.0261)	
walktime					0.0013
					(0.0012)
walktime*(construction & operations phases)					0.0017*
					(0.0010)
N	17,120	17,120	17,120	17,120	17,120
F-statistic	223.741***	223.594***	222.860***	222.136***	222.764***
R^2	0.839	0.839	0.839	0.840	0.839
Adj. R^2	0.835	0.836	0.836	0.836	0.835

Standard errors are in parentheses and are clustered at the Census block group level. *** denotes significance at the one percent level, ** at the five percent level, and * at the ten percent level. Each model includes unreported Census block group fixed effects, (month x year) fixed effects, and indicator variables for the home's high school district, the home's ownership type (5 categories), style of the home (22 categories), interior features (12 categories), and exterior features (18 categories). Our sample includes all sales from July 2002 through August 2016. LRT is a treatment indicator for homes within 1500 meters of an actual light rail station, while within800m and within1500m are indicators for homes between 0 and 800 meters and between 800 and 1500 meters of a station, respectively.

spread. The sale-list price spread allows us to jointly examine the perceptions of value from the light rail by buyers and sellers. It is possible that sellers expect to receive a premium from being near the light rail, leading to a higher original listing price and subsequently a larger deviation between the list and actual sale price. The sale-list price spread is the log difference between the final selling price and the

Table 4
Price Spread Results (ln(sale)-ln(list)) (control group=homes within 1500 m of proposed stations).

	(1) Price Spread	(2) Price Spread	(3) Price Spread	(4) Price Spread	(5) Price Spread
age	-0.0008***	-0.0008***	-0.0008***	-0.0008***	-0.0008***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
agesq	0.0000**	0.0000**	0.0000**	0.0000**	0.0000**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
sqft	0.0017	0.0017	0.0016	0.0017	0.0015
	(0.0082)	(0.0081)	(0.0082)	(0.0082)	(0.0082)
sqftsq	-0.0036**	-0.0036**	-0.0036**	-0.0036**	-0.0036**
	(0.0015)	(0.0015)	(0.0015)	(0.0015)	(0.0015)
bedrooms	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001
	(0.0020)	(0.0020)	(0.0020)	(0.0020)	(0.0020)
full baths	0.0124***	0.0124***	0.0124***	0.0124***	0.0124***
	(0.0028)	(0.0028)	(0.0028)	(0.0028)	(0.0028)
half baths	0.0083***	0.0083***	0.0083***	0.0083***	0.0083***
	(0.0029)	(0.0029)	(0.0029)	(0.0029)	(0.0028)
waterfront	-0.0140***	-0.0140***	-0.0141***	-0.0141***	-0.0136***
	(0.0050)	(0.0050)	(0.0050)	(0.0050)	(0.0050)
new home	0.0268***	0.0268***	0.0268***	0.0267***	0.0264***
	(0.0070)	(0.0070)	(0.0069)	(0.0068)	(0.0071)
pool	0.0061*	0.0061*	0.0060*	0.0060*	0.0060*
	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0034)
off street parking	-0.0032	-0.0032	-0.0032	-0.0032	-0.0034
	(0.0028)	(0.0028)	(0.0028)	(0.0028)	(0.0028)
reo	-0.0389***	-0.0389***	-0.0389***	-0.0389***	-0.0393***
	(0.0054)	(0.0054)	(0.0054)	(0.0054)	(0.0054)
short sale	-0.0820***	-0.0820***	-0.0820***	-0.0820***	-0.0816***
	(0.0103)	(0.0102)	(0.0103)	(0.0103)	(0.0102)
LRT	0.0071	0.0071			
	(0.0176)	(0.0177)			
LRT*(construction & operations phases)	-0.0195***				
	(0.0050)				
LRT*(construction phase)		-0.0203***			
		(0.0073)			
LRT*(operations phase)		-0.0190***			
		(0.0047)			
within800m			0.0077	0.0078	
			(0.0185)	(0.0186)	
within1500m			0.0048	0.0049	
			(0.0179)	(0.0180)	
within800m*(construction & operations phases)			-0.0224***		
			(0.0072)		
within1500m*(construction & operations phases)			-0.0167***		
			(0.0054)		
within800m*(construction phase)				-0.0221*	
				(0.0117)	
within1500m*(construction phase)				-0.0186**	
				(0.0074)	
within800m*(operations phase)				-0.0226***	
				(0.0060)	
within1500m*(operations phase)				-0.0155***	
				(0.0058)	
walktime					-0.0004*
					(0.0002)
walktime*(construction & operations phases)					0.0006***
					(0.0002)
N	17,117	17,117	17,117	17,117	17,117
F-statistic	10.390***	10.363***	10.339***	10.287***	10.313***
R^2	0.195	0.195	0.195	0.195	0.194
Adj. R^2	0.176	0.176	0.176	0.176	0.175

Standard errors are in parentheses and are clustered at the Census block group level. *** denotes significance at the one percent level, ** at the five percent level, and * at the ten percent level. Each model includes unreported Census block group fixed effects, (month x year) fixed effects, and indicator variables for the home's high school district, the home's ownership type (5 categories), style of the home (22 categories), interior features (12 categories), and exterior features (18 categories). Our sample includes all sales from July 2002 through August 2016. LRT is a treatment indicator for homes within 1500 meters of an actual light rail station, while within800m and within1500m are indicators for homes between 0-800 meters and between 800-1500 meters of a station, respectively.

original listing price for a property. A positive price spread means the final sale price was higher than the original list price.

The results in Table 4 shows that on average homes were sold at a lower price than original asking price compared to the control group. The first column shows the cumulative effect for both the construction and operation phases of the light rail system. In particular, homes

Table 5
Time-on-Market (control group=homes within 1500 m of proposed stations).

	(1) Time-on-Market	(2) Time-on-Market	(3) Time-on-Market	(4) Time-on-Market	(5) Time-on-Market
age	-0.2722	-0.2813	-0.2747	-0.2856	-0.2408
	(0.3262)	(0.3299)	(0.3237)	(0.3295)	(0.3234)
agesq	0.0024	0.0025	0.0024	0.0025	0.0021
	(0.0026)	(0.0026)	(0.0026)	(0.0026)	(0.0026)
sqft	4.7042	4.5967	4.6693	4.4768	4.8624
	(5.8988)	(5.9322)	(5.8978)	(5.9639)	(5.7908)
sqftsq	1.1817	1.1877	1.1841	1.1970	1.1454
	(0.9488)	(0.9523)	(0.9554)	(0.9623)	(0.9350)
bedrooms	-1.5773	-1.5872	-1.5444	-1.5474	-1.6424
	(1.6349)	(1.6393)	(1.6352)	(1.6426)	(1.6281)
full baths	-2.7465	-2.7094	-2.7708	-2.7145	-2.7603
	(1.8440)	(1.8381)	(1.8526)	(1.8418)	(1.8530)
half baths	-4.1508**	-4.1385**	-4.2574**	-4.2577**	-4.3079**
	(1.9699)	(1.9653)	(1.9471)	(1.9355)	(1.9265)
waterfront	9.9669**	9.8457**	10.0677**	9.9403**	10.1325**
	(4.6680)	(4.6164)	(4.7913)	(4.7175)	(4.7661)
new home	16.8631	16.8598	16.8103	16.9148*	17.0596
	(10.6063)	(10.4679)	(10.5304)	(10.2576)	(10.4111)
pool	-5.3835	-5.6333	-5.3097	-5.5344	-4.8985
	(3.4205)	(3.4417)	(3.3969)	(3.4139)	(3.3566)
off street parking	3.1229*	3.1399*	3.1248*	3.0923*	3.1254*
	(1.6830)	(1.6828)	(1.6784)	(1.6784)	(1.6743)
reo	-9.3253***	-9.3518***	-9.3448***	-9.3544***	-9.0516***
	(2.9172)	(2.9121)	(2.8772)	(2.8603)	(2.8878)
short sale	94.1647***	94.2834***	94.0911***	94.1691***	94.1619***
	(6.8142)	(6.8077)	(6.8106)	(6.8040)	(6.7736)
LRT	-44.2330***	-44.1252***			
	(15.1408)	(14.9652)			
LRT*(construction & operations phases)	6.2924				
	(4.8760)				
LRT*(construction phase)		0.0637			
		(5.2415)			
LRT*(operations phase)		10.1803*			
		(5.9095)			
within800m			-48.5711***	-48.8040***	
			(16.0067)	(15.9104)	
within1500m			-40.7524***	-40.7749***	
			(15.2543)	(15.1591)	
within800m*(construction & operations phases)			10.3967		
			(7.4067)		
within1500m*(construction & operations phases)			2.3036		
			(3.9758)		
within800m*(construction phase)				1.2586	
				(6.3496)	
within1500m*(construction phase)				-1.0515	
				(5.4686)	
within800m*(operations phase)				15.8365*	
				(9.3552)	
within1500m*(operations phase)				4.5651	
				(3.9531)	
walktime					0.0878
					(0.2114)
walktime*(construction & operations phases)					-0.4063
					(0.2737)
N	17,114	17,114	17,114	17,114	17,114
F-statistic	9.429***	9.432***	9.394***	9.382***	9.407***
R^2	0.180	0.181	0.180	0.181	0.180
Adj. R^2	0.161	0.162	0.161	0.162	0.161

Standard errors are in parentheses and are clustered at the Census block group level. *** denotes significance at the one percent level, ** at the five percent level, and * at the ten percent level. Each model includes unreported Census block group fixed effects, (month x year) fixed effects, and indicator variables for the home's high school district, the home's ownership type (5 categories), style of the home (22 categories), interior features (12 categories), and exterior features (18 categories). Our sample includes all sales from July 2002 through August 2016. LRT is a treatment indicator for homes within 1500 meters of an actual light rail station, while within800m and within1500m are indicators for homes between 0-800 meters and between 800-1500 meters of a station, respectively.

within 1500 meters of a station sold for approximately 2% less than the original asking price compared to the control group. Column (2) shows that the decline in the sale-list price spread is similar during the construction and the operation phase. In contrast, columns (3) and (4) highlight a slightly larger decline in the price spread among properties within 800 meters of a station relative to the control group. The final column, column (5), displays the walk-distance gradient. The positive coefficient for *walktime * (construction & operations phases)* means

Table 6
Robustness Checks Using Alternative Control Groups.

	(1) Log(Sale Price)	(2) Log(Sale Price)	(3) Price Spread	(4) Price Spread	(5) Time-on-Market	(6) Time-on-Market
age	-0.0088***	-0.0100***	-0.0009***	-0.0007	-0.2831	-0.5699
	(0.0010)	(0.0013)	(0.0003)	(0.0006)	(0.3997)	(0.4987)
agesq	0.0001***	0.0001***	0.0000**	0.0000	0.0025	0.0044
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0031)	(0.0038)
sqft	0.5584***	0.5980***	0.0028	-0.0003	3.2772	2.9327
	(0.0543)	(0.0679)	(0.0095)	(0.0133)	(5.4929)	(7.0615)
sqftsq	-0.0543***	-0.0596***	-0.0037**	-0.0041*	0.9740	0.9532
	(0.0098)	(0.0120)	(0.0017)	(0.0023)	(0.8152)	(0.9534)
bedrooms	0.0077	0.0013	-0.0013	0.0019	-0.7197	-0.9401
	(0.0068)	(0.0092)	(0.0022)	(0.0033)	(1.5788)	(2.1064)
full baths	0.0910***	0.0990***	0.0135***	0.0163***	-2.5805	-2.8995
	(0.0106)	(0.0143)	(0.0032)	(0.0046)	(1.9030)	(2.4902)
half baths	0.0515***	0.0737***	0.0092***	0.0204***	-3.7204**	-5.9626**
	(0.0134)	(0.0190)	(0.0034)	(0.0056)	(1.8824)	(2.6315)
waterfront	0.1433***	0.1607***	-0.0139***	-0.0198**	11.0562**	12.1480**
	(0.0183)	(0.0179)	(0.0053)	(0.0081)	(4.9781)	(5.9333)
new home	0.0794***	0.0633***	0.0303***	0.0371*	11.4715	5.0888
	(0.0171)	(0.0201)	(0.0083)	(0.0206)	(12.3908)	(15.1840)
pool	0.0320**	0.0259	0.0049	0.0030	-5.8097	-9.4045**
	(0.0139)	(0.0202)	(0.0037)	(0.0067)	(3.7746)	(3.7811)
off street parking	-0.0061	-0.0008	-0.0039	-0.0037	2.7885*	2.5641
	(0.0073)	(0.0104)	(0.0032)	(0.0037)	(1.6201)	(2.1480)
reo	-0.3093***	-0.3592***	-0.0415***	-0.0533***	-7.5002**	-8.2010**
	(0.0175)	(0.0206)	(0.0058)	(0.0076)	(2.9601)	(3.9769)
short sale	-0.2144***	-0.2251***	-0.0855***	-0.0931***	98.3754***	101.2053***
	(0.0161)	(0.0208)	(0.0117)	(0.0181)	(6.6283)	(9.3417)
within800m	0.0205	-0.0475	0.0106	-0.0217	-48.2017***	-44.6981***
	(0.0869)	(0.0865)	(0.0196)	(0.0211)	(14.7600)	(15.9448)
within1500m	0.0535	-0.0165	0.0075	-0.0212	-40.9787***	-38.8719**
	(0.0854)	(0.0869)	(0.0189)	(0.0194)	(14.0236)	(15.2176)
within800m*(construction & operations phases)	-0.0841***	-0.0863***	-0.0248***	-0.0221**	15.2346**	16.0366**
	(0.0261)	(0.0302)	(0.0073)	(0.0103)	(6.7318)	(8.0138)
within1500m*(construction & operations phases)	-0.0686***	-0.0720***	-0.0184***	-0.0177**	6.5149*	8.2458
	(0.0213)	(0.0265)	(0.0055)	(0.0083)	(3.4101)	(5.9926)
Control group	Proposed less oceanfront	Distance	Proposed less oceanfront	Distance	Proposed less oceanfront	Distance
N	14,014	8446	14,012	8446	14,008	8446
F-statistic	190.047***	133.683***	9.220***	4.269***	8.657***	5.583***
R^2	0.838	0.843	0.201	0.146	0.191	0.183
Adj. R^2	0.834	0.836	0.179	0.112	0.169	0.150

Standard errors are in parentheses and are clustered at the Census block group level. *** denotes significance at the one percent level, ** at the five percent level, and * at the ten percent level. Each model includes unreported Census block group fixed effects, (month x year) fixed effects, and indicator variables for the home's high school district, the home's ownership type (5 categories), style of the home (22 categories), interior features (12 categories), and exterior features (18 categories). Our sample includes all sales from July 2002 through August 2016. LRT is a treatment indicator for homes within 1500 meters of an actual light rail station, while within800m and within1500m are indicators for homes between 0 and 800 meters and between 800 and 1500 meters of a station, respectively.

that the final sale price increased relative to the list price as distance from a light rail station increased.

These results indicate that sellers experience a decrease in the final sale price relative to the original list price due to the introduction of the light rail system. However, sellers expectations about the value of their property play an important role in evaluating changes in the sale-list price spread. For instance, one potential explanation for the negative effect on the sale-list price spread is that sellers, based on selected experiences in other areas, expect their property to appreciate in value due to light rail. This could result in some sellers attempting to price that premium in the original list price, which could decrease the sale-list spread. Further, if potential buyers do not value light rail's benefits over the potential costs then the reduction in offer values and subsequently sales amount could effect the price spread.

5.3. Time-on-market

Table 5 provides results for time-on-market for properties within 1500 meters of a constructed or proposed light rail station. This provides a measure of how access to light rail transit effects the liquidity of a property. The time-on-market is a measure that is often noted by real estate agents and can be used by the buyer or seller during negotiations. Furthermore, our estimates provide some evidence on whether or not light rail access heats up or cools down a localized real estate market compared to the control group.

The results show that, on average, properties near constructed light rail stations experiences a positive, but largely statistically insignificant increase in the days a property is on the market. This is consistent among specifications and distances from the rail station. The point coefficient is larger, approximately 10 extra days on the market, after

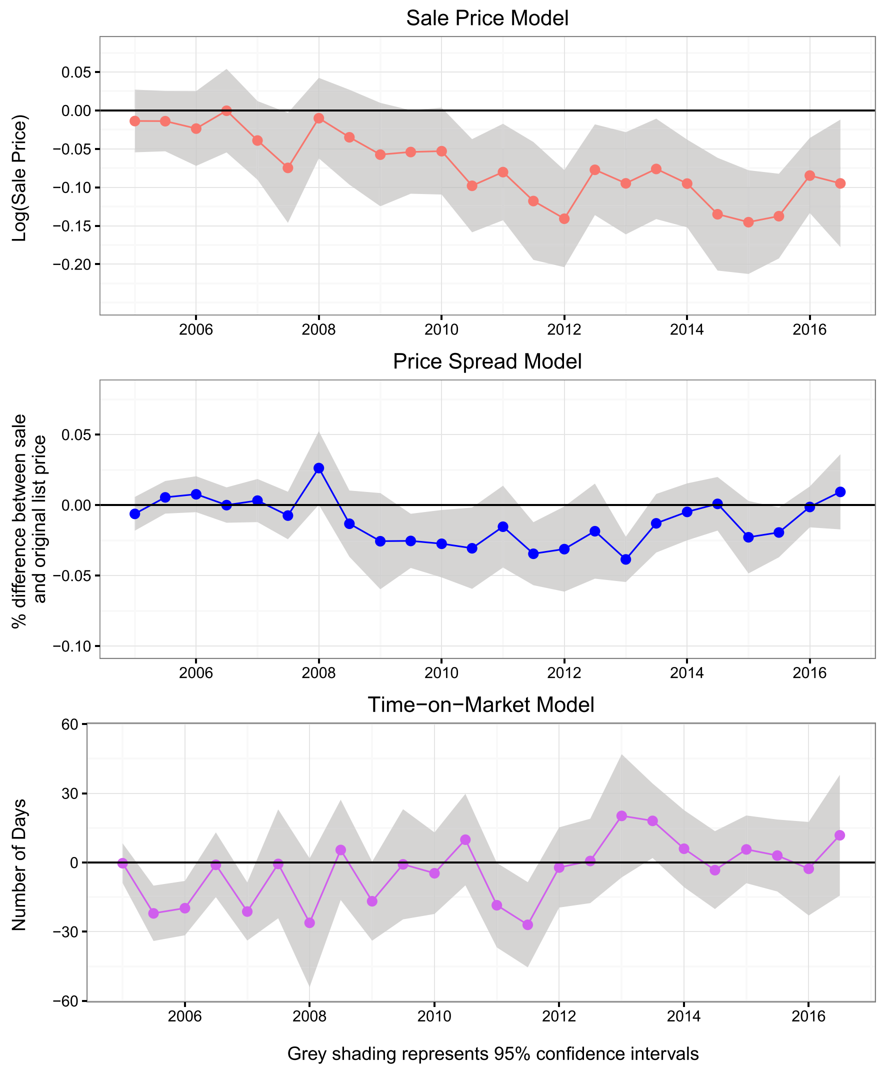

Fig. 2. Results from Dynamic Models.

the light rail began operations and statistically significant at the 10% level (column (2)). The estimates in column 4 indicates that this slight increase in time-on-market is driven entirely by properties within 800 meters of a station.

6. Robustness checks and dynamic results

In this section we provide results for the dynamic model depicted in Eq. (2) and also present estimates using two alternative control groups to examine the robustness of the primary results discussed in Section 5. The dynamic model (Eq. (2)) yields insights into how the residential real estate market evolved over time as a result of light rail and it also allows us to test the pre-existing trend assumption underlying our baseline difference-in-difference results.

Estimates using the alternative control groups are presented in Table 6. For each of our three outcome variables we estimate one specification (identical to column (3) in Tables 3, 4, and days) using each of the two alternative control groups for a total of six regressions. Columns (1) and (2) show the results for the sale price model, columns (3) and (4) show the sale-list price spread model, and columns (5) and (6) display the time-on-market estimates.[15]

[15] Robustness checks of columns (1), (2), (4), and (5) from our baseline results were omitted to conserve space. They are also qualitatively similar to the baseline results and can be provided upon request.

The first alternative control group uses homes sold within 1500 meters of proposed stations as the control group but differs from our baseline results in that we exclude homes sold close to the proposed Virginia Beach oceanfront stations (stations P12 and P13 on Fig. 1). This part of Virginia Beach is primarily focused on recreation and tourism, and the homes near these proposed stations might not be an appropriate control group for the constructed Tide light rail stations that are much further away from similar amenities. These estimates are labeled 'Proposed less oceanfront' in Table 6. In addition, we define a second control group that is based on a more conventional distance-based threshold and rely on residential sales that occurred between 1500 and 3600 meters away from the constructed stations as the control group. These results are labeled 'Distance' in Table 6.

As the estimates show, the magnitude and statistical significance of the coefficients of interest are very similar across all of our outcome variables in Table 6 relative to our baseline specifications. For instance, in the sale price regressions (columns (1) and (2)) we find that homes located within 800 meters of a constructed station fall by 8.4% using the alternative proposed station control group and by 8.6% when using the distance-based control group. Our baseline specifications (column (3)) in Table 3 estimate the total reduction from the construction and operations phases to be 8.6%. One notable difference between the baseline regressions and the robustness specifications is that we find stronger evidence that homes closer to light rail stations remain on the market longer in the results presented in Table 6. While our baseline model (column (3)) in Table 5 indicates that homes within 800 meters of a station remain on the market for 10 days longer (but this is not statistically significant), the robustness checks in columns (5) and (6) show this effect to be between 15 and 16 days longer and to be statistically significant at the 5% level.

We also estimate Eq. (2) to examine the dynamic nature of the residential real estate market response to light rail transit. The model uses the same property level data and control variables as our baseline results and also includes our full sample of data so that we are considering as much information as possible in the pre-construction period. However, we now use a light rail treatment indicator interacted with time indicators for every 6-month time period. The baseline in the estimated dynamic models is the year 2003. This helps to shed light on the key assumption behind the difference-in-difference research design. A causal interpretation of the findings would be weakened if the real estate market outcomes were changing before construction began.

The dynamic results are displayed in the three panels in Fig. 2, with the sale price results in the top panel, the sale-list price spread in the middle panel, and the time-on-market model displayed in the bottom panel. In each figure the solid line represents estimated coefficients for the 6-month indicators, while the shaded area is the 95% confidence interval. The log sale price depicted in Fig. 2 shows the estimated difference in the treated and control group compared to the baseline year 2003. The average estimated difference for each 6-month period between 2004 and 2006 is statistically indistinguishable from zero at the 5% level. It also shows that the average sale price difference for homes near light rail stations began to fall during the construction phase and remained negative and statistically different from the control group homes throughout the construction and operation phases. This provides evidence that the sale price results are not driven by differing pre-existing trends for the treatment and control groups.

Next, the middle and lower panels in Fig. 2 show similar graphs for the sale-list price spread and time-on-market. These figures also provide some evidence that the results for each outcome measure were not driven by pre-existing trends, but the estimated treatment effect in these figures are not as conclusive as the log sale price model. However, the results do suggest a negative average treatment effect for the sale-list price spread in the construction and operations phases. Dynamic results, like those displayed in Fig. 2 can be plagued with large standard errors due to the high correlation between the treatment and time interactions.

7. Conclusion

Operational and proposed light rail transit systems often sharply divide communities because of the reliance on public funds to finance construction costs and subsidize operating expenses. Researchers have often turned to the real estate market to examine the impact of light rail on local communities. This study adds to this growing literature by estimating the effect of the Norfolk Tide light rail on three residential real estate market outcomes: the real sale price, sale-list price spread, and time-on-market. We accomplish this by using a difference-in-differences empirical model. Our identification strategy exploits a proposed, but not constructed rail line in neighboring Virginia Beach, Virginia as the control group.

Our estimates show that the Tide light rail system had a negative effect on homes within 1,500 meters of constructed stations. The estimates show that, on average, the sale price declined in actual light rail neighborhoods relative to the control group by 7.8% following the start of the construction phase and including the operational phase. Thus, using our preferred hedonic pricing estimate, the aggregate decline in housing values due to the light rail was approximately $75 million, which is more than 20% of the original construction costs.[16] Furthermore, homes within 1500 meters of a station sold for approximately 2% less than the original listing price compared to homes in the control group. We also find limited evidence that the time-on-market increased for homes around light rail stations after the Tide began operating relative to our control group properties.

It is useful to put our results into context based on the academic literature. The previous quasi-experimental studies focused on the effect of light rail transit on residential housing prices in large metropolitan areas. These studies examined either the construction of a new light rail system or the opening of new stations and service frequency for long-standing rail transit lines, and generally show a positive effect for rail transit on residential housing. Billings (2011) estimates a 4% increase in the sale price for single family homes in Charlotte, while McMillen and McDonald (2004) note an average increase of $6000 in Chicago. Gibbons and Machin (2005) and Dubée et al. (2013) both examine the expansion of an existing rail line for London and Montreal, respectively, and find positive effects on home values. In contrast, Gatzlaff and Smith (1993) find only weak evidence that the announcement of the Miami Metrorail system positively impacted residential home values. Each of the cities in the previous (quasi-experimental) literature have a larger and more dense population along with notably higher ridership figures than Norfolk. This suggests that the connectivity of the rail transit lines in these cities provide arguably greater accessibility benefits to homeowners living near stations. Hence, the estimated capitalization effects of the rail lines on the real estate market are larger than the Norfolk Tide.

The results reported in this paper measure the effect of the Tide light rail on the residential housing market for the construction phase and the first 5 years after the start of operations. Thus, the results are limited in the benefits and costs to light rail that are capitalized in the housing market. For instance, our estimates do not include benefits from any future transit oriented economic activity that could be capitalized by homeowners near Tide stations, nor do they include any increases in accessibility from future rail line expansions or general equilibrium effects to the area as a whole from reduced traffic congestion and pollution or business attraction. Hence, our results are useful to metro areas that are considering building a starter line that could be expanded in the future and to light rail systems with potentially low ridership and low accessibility benefits. Our results suggest that light rail proponents should take caution in encouraging projects that do not provide accessibility benefits that outweigh any potential costs.

[16] The aggregate reduction in home values due to the light rail construction and opening was calculated as the average effect of the light rail * the average value of effected homes after construction began * total number of homes effected by the light rail (−7.8% * $234,800 * 4138).

Appendix A. Additional home characteristics

(Table A.1).

Table A.1
Complete List of Home Characteristics Accounted for in Empirical Models.

Interior Features	Exterior Features	Style Features	Ownership Type
gas fireplace	barn	2 unit condo	simple
pull-down attic access	cul-de-sac	apartment	condo
walk-in closet	deck	bungalow	cooperative
window treatments	golf course lot	cape cod	timeshare
skylights	greenhouse	cluster	leasehold
scuttle access	gazebo	colonial	
wood burning stove	horses allowed	contemp	
bar	inground sprinklers	cottage	
permanent attic stairs	irrigation control	farmhouse	
master bedroom fireplace	tagged items	hi-rise	
cedar closet	patio	mobilie home	
handicap access	pump	modular	
	rain water harvesting	other	
	shed	quadraville	
	stables	ranch	
	tennis	spanish	
	wells	split-level	
	wooded	townhouse	
		traditional	
		tri-level	
		twinhouse	
		victorian	

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