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Abstract

It seems an article-of-faith that real estate markets respond more favorably to location within one-half mile of transit stations. Planning and public decision-makers have thus drawn half-mile (or smaller) circles around rail transit stations assuming larger planning areas would not be supported by the evidence. Recent research, however, has shown market-responsiveness well beyond one-half mile. We contribute to this literature by evaluating the distance-decay function of office rents in metropolitan Dallas and Denver with respect to light rail transit (LRT) station distance. Using a quadratic transformation of distance we find office rent premiums extending in the range of two miles away from LRT stations with half the premium dissipating at about two-thirds on one mile and three quarters dissipating at about one mile. We offer planning and policy implications including the need to expand LRT station planning areas, perhaps considerably.

Introduction

Almost all forms of transportation have an economic development function as they connect people and/or goods from an origin to a destination usually in an economic exchange (1). Transportation systems can lead to agglomeration economies in certain industries by reducing the time and distance between them, their labor force, and markets (2, 3). Those economies can lead to higher population and employment densities that can increase overall economic activity (4, 5). Agglomeration economies combined with increasing population and employment density can tax highways, however, leading to congestion, reduced productivity, and ultimately diseconomies associated with agglomeration. A key role of transit is to mitigate transportation congestion effects of agglomeration. Voith (6) characterizes public transit as essentially "noncongestible" and is best suited to sustaining agglomeration economies in downtowns and secondary activity centers, and along the corridors that connect them. Nonetheless, not all economic sectors benefit from agglomeration economies and/or density.

There is a growing body of research showing that rail-based public transit enhances economic development (7, 8, 1). These economies are facilitated when they improve accessibility between people and their destinations by reducing travel time relative to alternatives. At the metropolitan scale, adding transit modes in built-up urban areas increases aggregate economic activity (9).

Economic development can be measured in many ways. A key way is by evaluating how the real estate market responds to the presence of transportation investments, such as rail systems. Higher property values closer to stations implies market capitalization of economic benefits. There are numerous studies assessing the market premium associated with residential property (10, 11, 12). As Ko and Cao (13) point out, however, there are fewer studies associating rail benefits with respect to nonresidential property values. We help close this gap in literature.

We begin with a literature review. We follow with a review of the role of hedonic analysis in uncovering important relationships transit accessibility and nonresidential property values. We identify two large metropolitan areas, Dallas and Denver, as reasonable candidates for hedonic analysis. Next, we present our research design, model, data, and variables. This is followed by results and implications.

1. The role of hedonic analysis in estimating market responsiveness to transit

Based on work by Iacono and Levinson (14) we are grateful to Ko and Cao (13) for observing that previous studies into economic outcomes associated with rail transit used meta-analysis of transit premiums, benefit-cost analysis, and production functions. We are also grateful to both sets of authors for making the claim, which we accept, that hedonic pricing models are the most appropriate for estimating the real estate market's willingness to pay for accessibility to rail transit service. The reason is that the hedonic model decomposes goods (such as homes) that are bundles of individual attributes (such as house size, lot size, bedrooms, bathrooms, neighborhood location and so forth) into implicit prices for each of the attributes, pioneered by Rosen (15). Therefore, the value of a property is the summation of implicit prices for the characteristics associated with the property, such as location and structural attributes.

Hedonic real estate property analysis has thus emerged as a key way in which to assess market responsiveness to public transit investments (16). A key reason hedonic modeling has gained in popularity is the increasing availability of data that can be collected at a small scale, such as specific properties, combined with the ability to measure distances from a parcel to discrete places such as downtowns, suburban centers, and transportation facilities. Hedonic analysis is also objective. Unlike contingent valuation and stated preference surveys wherein respondents assign values to attributes under varying degrees of controls, hedonic analysis estimates the revealed preferences of those attributes through marginal valuation techniques – mostly multivariate regression analysis. We refer readers to Bartholomew and Ewing (16) for their detailed review of literature on the role of hedonic analysis in estimating market responsiveness to transit.

Bartholomew and Ewing also synthesize literature and key findings from dozens of studies estimating the market's willingness to pay for transit accessibility. However, nearly all of the studies they reviewed were of single family residential and occasionally multifamily rental property sales. The reason is that to be statistically reliable and valid, a large number of cases are needed for regression techniques to estimate the variation in the willingness of consumers to pay more for specific property attributes (such as a larger home) even if at a declining rate (the next square foot of a home is usually not as valuable as the last one). While local property assessor data bases are large, many unfortunately do not provide reliable property valuation data. Many researchers thus seek access to actual sales prices of properties and their attributes.

The data needs of hedonic analysis thus often work against applying this technique to nonresidential properties. For one thing, there are far fewer nonresidential than residential properties. For another, while the principal market purpose of residential properties is to house people, nonresidential properties serve very different market purposes such as offices, retail, hospitality, health, and industry among others. Moreover, acquiring sales data for a sufficient number of nonresidential cases with which to conduct hedonic analysis is often difficult. It is for these reasons and others that the number of hedonic studies of nonresidential properties with respect to transit accessibility are far fewer than for residential property.

We are indebted to a recent review of the relevant nonresidential property hedonic literature by Ko and Cao (13) both identifying these and other limitations, and reviewing results of the relatively few studies applying hedonic regression analysis to nonresidential property.

For instance, while many studies find a negative relationship between rail transit distance and sales prices of nonresidential properties, most studies show positive relationships (17, 18, 19, 20), about as many others find positive associations (21, 22, 23, 24, 25). Reasons for negative outcomes may be unsafe surroundings at rail transit stations or poor accessibility to destinations on-foot after disembarking. In their assessment of all studies reported to the middle 2000s, Debrezion, Pels, and Rietveld (10) summarized a range of property value impacts from -62 percent to 145 percent within and beyond one-quarter mile of rail transit stations with an average impact of about 16 percent.

One limitation of many of the earlier studies is using discrete distance bands around stations, such as using binary variables to note whether a property was within one-half mile of a station or not (1,0). In citing Weinberger's work (25), Ko and Cao argue that measuring continuous distance from stations allows analysts to determine the slope of a distance gradient. Further, if a nonlinear function is used, especially a quadratic transformation of the station-distance variable, the outward extent to which station proximity confers value can be estimated (26, 27, 28).

For their part, Ko and Cao developed hedonic valuation models to assess the implicit value of office and industrial properties within one-mile buffers of the Hiawatha LRT stations based on sales data of such properties sold before and after the line was completed. They find that the LRT line confers significant price premiums for office and industrial properties to about 0.9 miles from LRT stations, or just about the full extent of their study area.

Our paper contributes to the literature in ways that both confirm and confound prior work.

2. Metropolitan Dallas and Denver study areas

We extend work of others including Ko and Cao by evaluating the office rent premium associated with light rail transit station proximity in metropolitan Dallas and Denver. We chose those systems for four reasons. First, they are among the oldest LRT systems in the US. The Dallas Area Rapid Transit (DART) system began LRT service in 1996 while metropolitan Denver's Regional Transportation District began operating its FasTracks LRT in 1994. Only Portland's (1986), Sacramento's (1987) and San Diego's (1981) LRT systems are older.

Second, unlike Portland, Sacramento and San Diego, DART and FasTracks serve metropolitan areas that are largely sprawling metropolises undeterred by terrain (the Rocky Mountains are scores of miles away from downtown Denver) and policy (neither explicitly contains urban development).

Third, they are among the nation's largest LRT systems. In 2012, DART had 60 stations and nearly 100,000 daily passengers while FasTracks had 46 stations and nearly 90,000 daily passengers.

Fourth, their sheer size allow for sufficient data on office rents to undertake hedonic analysis (as we discuss below).

3. Research design, model, data and variables

Our study area is five miles within all LRT stations open or under construction in metropolitan Dallas and Denver in fall 2012. It is thus the largest study area of any study of its kind. We employ the following hedonic model in our analysis:

$R_i = f(B_i, S_i, C_i, L_i)$

where:

R is the market rent per square foot for property *i*;

B is the set of building attributes of property *i*;

S is the set of socioeconomic characteristics of the vicinity of property *i*;

C is a composite measure of urban form of the vicinity of property *i*; and

L is a set of location attributes of property *i*.

Our dependent variable, R or rent per square foot, and independent variables comprising B, building attributes, come from CoStar, with permission. Through proprietary access during fall 2012, we were able to collect an inventory of all office buildings within the study area including their address, square feet, occupied and vacant space, stories, effective age (by the later of the construction or renovation year), building class (A, B and C), and weighted average contract rent per square foot though we do not have lease terms for individual tenants. These variables include:

Class A
Class B
Gross Leasable Square Feet
Floor Area Ratio (Gross Leasable Square Feet divided by land area)
Vacancy Rate
Effective Year Built
Stories

Socioeconomic data comes from either the 2010 census (for percent census tract population that is not White non-Hispanic) or the 2012 5-year American Community Survey (for census tract median household income).

C is a unique variable which measures urban form from most sprawled/diffused/disconnected to most compact/integrated/connected at the level of the census tract. This index places urban sprawl at one end of a continuous scale and compact development at the other. The original index was developed in 2002 for metropolitan areas and counties (29, 30). In a recent study, the compactness indices were refined and updated to 2010 for metropolitan areas, urbanized areas, counties and census tracts and all are posted on a National Institutes of Health website (31).[1] For

[1] http://gis.cancer.gov/tools/urban-sprawl Accessed July 28, 2014.

census tract indices, Ewing and Hamidi used the same methodology and the same type of variables as in larger area analyses. They extracted principal components from multiple correlated variables using principal component analysis and transformed the first principal component to an index with the mean of 100 and a standard deviation of 25. Because the number of component variables is greater for street accessibility than land-use mix, and greater for land-use mix than development density, the resulting index gives more weight to street accessibility than mix, and to mix than density. This is not unintentional, since the built environment-travel literature suggests that density is the least important of the three D variable types (32). Given that retail land uses that depend especially on accessibility this is an appropriate composite variable to include.

Finally, L, the set of location variables, measures the distance of the centroid of each parcel to the center of central business district of Dallas or Denver, the nearest entrance onto a limited access highway and its quadratic term, and distance to the nearest LRT station and its quadratic term. Distances are measured in miles.

About three percent of all office properties in the CoStar data base do not have all data needed for our analysis, mostly as unreported rent per square foot. The Dallas data base includes 812 properties comprising about 118 million gross leasable square feet of building while the Denver data base includes 591 properties comprising about 67 million square feet. We believe this is the largest market-based data base for office properties collected and evaluated in the literature for our study purposes.

4. Results

Table 1 reports results of linear ordinary least squares regression separately for Dallas, Table 2 reports results for Denver, and Table 3 reports combined results. For all models, the coefficients of determination are reasonable (all are above 0.50), the correlation matrices (not reported for brevity) did not reveal problematic correlations, and autocorrelation was not detected.

INSERT TABLE 1 ABOUT HERE
INSERT TABLE 2 ABOUT HERE
INSERT TABLE 3 ABOUT HERE

In all regressions, the building structure variables performed reasonably. The difference in rents per square foot between Class A and Class B buildings (with Class C buildings as the referent) was substantial and expected. The incremental size of a building showed small increases in rent suggesting bigger buildings confer slightly more value in the market's willingness to pay (perhaps because they offer additional amenities that smaller building cannot). On the other hand, the number of stories in a building did not change mean rents per square foot statistically (Class A buildings by and large represent tall buildings) while increasing FAR (floor area ratio) is associated with decreasing rent though this is offset with results for building class. Increasing vacancy rates reduced mean rents while decreasing effective age increased rents at the margins.

The socioeconomic variables had expected results as increasing median household incomes were associated with increasing while increasing shares of population that were not White Non-Hispanic were associated with decreasing rents (although the coefficient in the Dallas regression was not significant).

The Compactness Index was also positive in all regression equations. While this is a composite variable, it suggests that on the whole the market is willing to pay more for locations that are more densely occupied by jobs and people, more integrated in terms of land use mix, and have well-connected streets compared to other locations.

The CBD distance location variables performed as expected but, while having the correct signs the variables measuring distance to nearest limited access highways are not statistically significant.

Of interest to us is the extent to which office rents are affected by proximity to LRT stations and if so how far away. In all equations, the coefficients are significant and have the anticipated signs; that is, as distance from an LRT station increases rents fall (negative coefficient on the distance variable) but at a declining rate (positive sign on the quadratic transformation). Differentiating the coefficients and then setting for zero, we solve for the distance threshold. In the Dallas regression results, we estimate the LRT station effect extends about 1.85 miles; for Denver we estimate the threshold extends about 3.30 miles; and in the regression for the pooled case we estimate the threshold extends about 2.35 miles.

5. Implications

Our estimated distance thresholds are much larger than those reported by Ko and Cao. There may be two reasons for this. First, our sample includes only offices while theirs includes industrial properties. We know from prior research that industrial employment around rail transit stations fall over time perhaps because other uses outbid such firms. We wonder what Ko and Cao's results would be if only office properties are used. Second, Ko and Cao measured effects only across the first mile from rail stations. This could have the effect of truncating the statistical results of the quadratic terms to "fit" within this spatial constraint.

On the other hand, solving for the rent premium effect continuously from zero to the premium threshold, we find that half the premium is lost by the first 0.50 mile, 0.75 mile, and 0.65 mile respectively, and three quarters are lost by the first 0.90 mile, 1.20 mile, and 1.10 mile respectively (see Figure 1). These thresholds are larger than conventional TOD planning practice which is based on the one-half mile circle protocol.

INSERT FIGURE 1 ABOUT HERE

This is not to say that people will walk one to three miles to/from LRT stations; they will not. But once disembarked from LRT, some may cycle to their trip end, connect with regularly scheduled bus service with short headways, or use specially-provide intra and inter TOD shuttles.

Planners and public officials may need to rethink assumptions underlying the half-mile circle. This is consistent with Canepa (33) who argued that combined with good urban design and multiple short-distance alternative modes (such as walking, biking, TOD-serving shuttles) there should be every reason to expect the market premium for land uses near rail transit stations to extend a mile and even well beyond a mile. That the office rent market capitalizes benefits of LRT station proximity so much farther away than previously thought means there are opportunities to maximize those benefits.

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Table 1
Hedonic Regression Results for Office Rent Premium with Respect to LRT Station Distance, Dallas

Variable	**Coefficient**	**Std Err of Coef.**	**t-score**	***p***
Constant	-56.137	18.623	-3.014	.01
Class A	7.329	0.528	13.869	.01
Class B	2.418	0.405	5.969	.01
Gross Leasable Square Feet	0.000	0.000	1.420	.10
Floor Area Ratio	-0.333	0.079	-4.237	.01
Stories	-0.018	0.041	-0.431	
Vacancy Rate	-0.024	0.005	-4.674	.01
Effective Year Built	0.035	0.009	3.689	.01
Median Household Tract Income	0.046	0.005	9.767	.01
Percent Not White Non-Hispanic	0.000	0.010	-0.025	
Compactness Index	1.095	0.366	2.995	.01
Distance from CBD, miles	-0.291	0.043	-6.777	.01
Distance from Interchange, miles	-0.133	0.633	-0.211	
Square Distance from Interchange, miles	0.322	0.264	1.221	
Distance Nearest LRT Station	-0.722	0.400	-1.803	.05
Squared Distance Nearest LRT Station	0.195	0.084	2.324	.01
R Square	0.542	0.533	3.52632	
Adjusted R Square	0.533			
Std. Error of the Estimate	3.526			
F	62.779			
Sig. F	0.000			
Observations	811			
Degrees of Freedom	796			
Durbin-Watson	1.710			

Table 2

Hedonic Regression Results for Office Rent Premium with Respect to LRT Station Distance, Denver

Variable	**Coefficient**	**Std Err of Coef.**	**t-score**	***p***
Constant	7.789	4.194	1.857	.01
Class A	7.859	0.664	11.837	.01
Class B	3.711	0.519	7.153	.01
Gross Building Square Feet	0.000	0.000	1.339	.10
Floor Area Ratio	-0.129	0.071	-1.807	.05
Stories	-0.015	0.061	-0.246	
Vacancy Rate	-0.023	0.007	-3.356	.01
Effective Year Built	0.006	0.002	2.712	.01
Median Household Block Group Income	0.023	0.007	3.123	.01
Percent Not White Non-Hispanic	-0.062	0.02	-3.089	.01
Compactness Index	0.146	0.442	0.331	
Distance from CBD, miles	-0.453	0.067	-6.811	.01
Distance from Interchange, miles	-1.802	0.778	-2.318	.01
Square Distance from Interchange, miles	0.666	0.265	2.516	.01
Distance from Nearest LRT Station	-1.406	0.531	-2.65	.01
Squared Distance from Nearest LRT	0.212	0.112	1.898	.05
R Square	0.506			
Adjusted R Square	0.494			
Std. Error of the Estimate	3.620			
F	39.343			
sig. F	0.000			
Observations	591			
Degrees of Freedom	575			
Durbin-Watson	1.945			

Table 3
Hedonic Regression Results for Office Rent Premium with Respect to LRT Station Distance, Dallas and Denver

Variable	Coefficient	Std Err of Coef.	t-score	*p*
Constant	0.400	3.971	0.101	
Class A	7.929	0.409	19.381	.01
Class B	3.209	0.320	10.025	.01
Gross Building Square Feet	0.000	0.000	0.881	
Floor Area Ratio	-0.164	0.051	-3.196	.01
Stories	-0.003	0.034	-0.092	
Vacancy Rate	-0.026	0.004	-6.079	.01
Effective Year Built	0.007	0.002	3.372	.01
Median Household Block Group Income, 2010	0.040	0.004	10.091	.01
Percent Not White Non-Hispanic	-0.013	0.009	-1.470	.10
Compactness Index	1.054	0.263	4.008	.01
Distance from CBD, miles	-0.260	0.035	-7.492	.01
Distance from Interchange, miles	-0.148	0.475	-0.311	
Square Distance from Interchange, miles	0.123	0.178	0.690	
Distance from Nearest LRT Station	-1.092	0.318	-3.432	.01
Squared Distance from Nearest LRT Station	0.232	0.067	3.461	.01
Denver	0.780	0.280	2.789	.01
R Square	0.509			
Adjusted R Square	0.503			
Std. Error of the Estimate	3.643			
F	89.717			
sig. F	0.000			
Observations	1,403			
Degrees of Freedom	1,386			
Durbin-Watson	1.779			

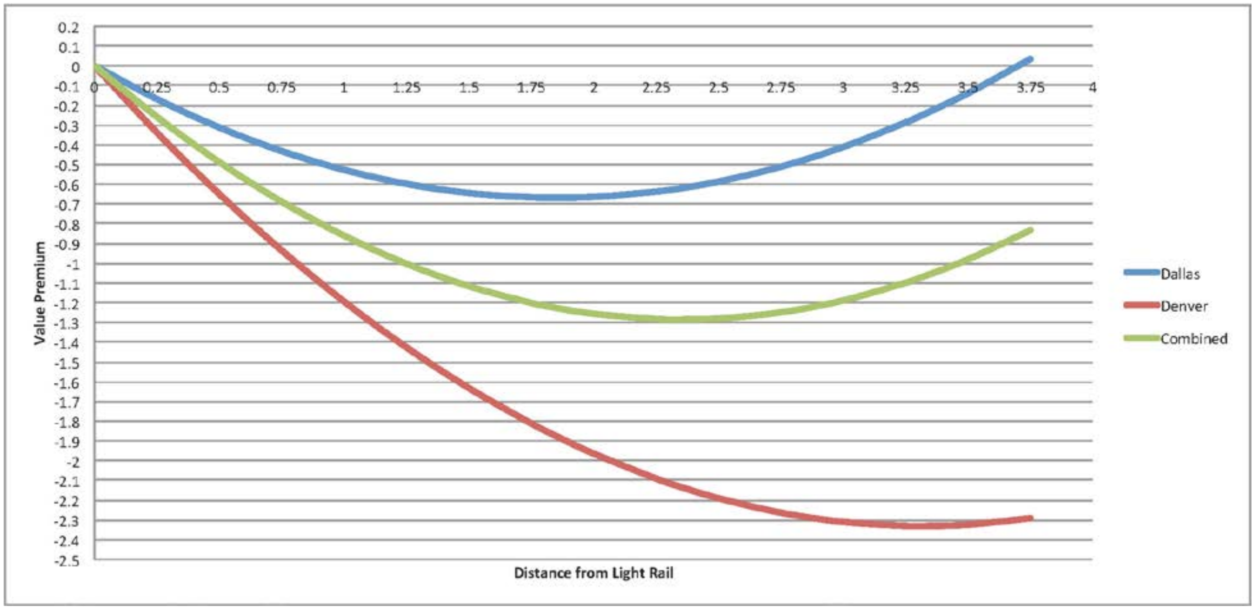

Figure 1
Office Rents with Respect to Light Rail Transit Station Distance