STREETCARS AND REAL ESTATE RENTS WITH IMPLICATIONS FOR TRANSIT AND LAND USE PLANNING

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ABSTRACT

Modern streetcars seemed to have emerged as the darling of America's downtown revival. Planners however have little experience with market responses to modern streetcars to help guide future efforts, or improve or expand current ones. This article is the first to report the association between real estate rents and proximity to streetcar stations based on all streetcar systems launched since 1990. It also uses multiple functional forms. The article shows that real estate rents increase the closer office, retail and multifamily properties are to streetcar stations. Analysis further tests outcomes using five functional forms: linear; semi-log; double-log; quadratic; and fine-grained distance band (using one-eighth mile increments). It appears that the distance band functional form specification may be more useful than others for transit and land use planning purposes. Results suggest that streetcar planning and associated land use planning should anticipate heightened demand for multifamily residential development near streetcar stations perhaps displacing office development to about a half mile away. Retail activities may benefit from additional level of competition for location near streetcar stations by both residential and office development. Indeed, analysis finds that whereas multifamily residential rent premiums with respect to streetcar station proximity extend a mile outward, office rent premiums are lower closer to stations but rise rapidly about a half mile away, presumable outbidding multifamily residential development. Retail activities take advantage of this competition roughly to the area between the office and multifamily rent premium thresholds. Implications for fixed guideway transit and land use planning practice are offered.

INTRODUCTION

American streetcars flourished from the 1880s through the 1940s. To make way for automobiles, they were mostly dismantled from the end of WWII to about 1960 [**1**]. What remained were mostly heritage and tourist-dominated streetcars such as those seen in San Francisco, Philadelphia and New Orleans. This began to change in the late 1990s through the rise of the so-called modern streetcar. It has its genesis in Portland, Oregon, which started operations in 2001. It is also the nation's most extensive streetcar network. Modern streetcars are no longer the charming relic of a bygone era but have become key transportation mode choice options especially in built up urban areas [**2**]. Since 2001, we count no fewer than 25 streetcar new systems in operation, under construction, or planned as of this writing.

Portland's streetcar goals are similar to those of other systems built or being planned. They include [**3**]:

Provide neighborhoods with convenient and attractive transportation alternatives.

Fit the scale and traffic patterns of existing neighborhoods.

Provide quality service to attract new transit ridership.

Reduce short inner-city auto trips, parking demand, traffic congestion and air pollution.

Encourage development of more housing and businesses in the city.

Yet, going on two decades, there has not been rigorous, systematic cross-section analysis of whether and the extent to which modern streetcars influence the real estate market. Our article helps close this gap.

In this article, we apply hedonic regression to estimate the association between streetcar station proximity and office, retail and multifamily rents using several functional forms. We apply our analysis to modern streetcar systems launched since the 1990s and operating in

Atlanta, Charlotte, Cincinnati, Dallas, the District of Columbia (DC), Kansas City, Little Rock, New Orleans, Portland, Salt Lake City, Seattle, Tacoma, Tampa, and Tucson. Our modeling approach is generalizable to other systems.

This article begins with the research questions and proceeds to theory, research design, general model, functional form, study area and specific model and data. This is followed by an assessment of how the real estate market appears to capitalize proximity to streetcar stations in the form of higher rents but that the nature of this rent uplift varies by functional form. We will suggest that for transit and land use planning purposes, a fine-grained distance-band functional form may be more informative than alternative ones.

RESEARCH QUESTIONS, THEORY, RESEARCH DESIGN, GENERAL MODEL, FUNCTIONAL FORM, STUDY AREA, SPECIFIC MODEL and DATA

Research Questions

Our research questions are simply:

> Is there an association between commercial real estate rent (per square foot) and proximity to streetcar stops holding other factors constant?

> Does the nature of association vary by functional form?

Theory

The questions are guided by theory. Conventional urban location theory developed by Alonso [**4**], Muth [**5**] and Mills [**6**] (also known as AMM) shows that in a monocentric city, where all jobs are in the central business district (CBD), the cost of transportation increases as distance increases from the CBD at a declining rate, as a function of increasing land area of the commuting shed. Transportation costs thus affect land value so that the "bid rent" curve for land also declines as distance increases. Where transportation costs are lowest, in the CBD, land prices are highest. To afford higher land prices ("rent") in the CBD, more economic exchange is needed, resulting in higher development intensities among office, retail, and high-value multifamily housing land uses among others. Economic activities that cannot compete for CBD locations are pushed outward to locations where they can outbid other land uses, a process called urban land use invasion and succession [**7**].

In relaxing the strict monocentric city model, one can imagine the same principles at work only at smaller scales that are distributed across a metropolitan area [**8**]. For instance, in focusing transportation activity at nodes, rail transit stations can become small version of CBDs. Economic activities will bid up land prices close to rail transit stations; lower value activity moves away from transitions to location there they can outbid competing land uses. Numerous studies show negative bid rent gradients with respect to distance from rail transit stations suggesting these local level outcomes [**9**].

Research Design

The theory can be evaluated through static, cross-section quasi-experimental research design. That is, using one period of time, one can test for the effect of streetcar station proximity on real estate rents across an area, such as a metropolitan area, and across multiple metropolitan areas with streetcar systems. Though analysis is not causative, associations can be used as guidance for transit and land use planning purposes nonetheless.

General Model

Using these theoretical and research design foundations as a guide, we develop the following general model to test the theory. It is adapted from Nelson [**10**]:

$$\mathbf{R}_i=\mathbf{f}(\mathbf{S}_i, \mathbf{SES}_i, \mathbf{P}_i, \mathbf{U}_i, \mathbf{L}_i, \mathbf{M}_i) \quad (1)$$

where:

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

S is the set of structural attributes of property *i* including its architecture, mass, height, age and effective age, interior amenities, flow efficiencies and so forth;

SES is the set of socioeconomic characteristics of the vicinity of property *i* such as population features, income, education;

P is a set of planning, zoning and other development restrictions applicable to property *i*;

U is a set of measures of urban form of the vicinity of property *i* such as the nature of surrounding land uses, terrain, physical amenities (such as parks), street characteristics and related;

L is a set of location attributes of property *i* such as distance to downtown and other activity centers, distance to nearest major highways including freeway/expressway ramps, and distance to different public transit options; and

M is a set of metropolitan area controls. As metropolitan area conditions and markets vary between them, identifying the location of property *i* within its respective market helps control for metropolitan-specific influences.

Functional Form

The choice of functional form and variable specification is important. Standard urban economic theory posits that land value will decline with distance from the CBD or other high activity nodes. Linear, semi-log, and double-log functional forms are the dominant forms reported in literature [**9**].

The *linear functional form* assumes a straight line deduction in property value with respect to distance away from a node, such as a transit station.

The *semi-log functional form*—where the dependent variable is logged—estimates the percent change in value associated with a unit change in an independent variable. If the dependent variable is price per square foot of real estate and the coefficient is -5.0, the semi-log interpretation is a $5.00 per square foot value reduction for each mile away from the station.

The *double-log functional form* generates elasticities—continuously measured variables on both sides of the equation are logged though categorical and binary variables are not. If the station distance coefficient is -0.50, the double-log estimates that a one percent increase in the distance from a transit station will reduce value by 0.50 percent per square foot.

None of those functional forms are very useful to planners who need to know how to arrange land uses to maximize economic benefits of transit stations. It may be that want to know whether the market will respond favorably to land use and density allocations with respect to distance from transit stations, and especially how far away. Lacking guidance from these conventional functional forms, planners have settled on quarter-mile and half-mile planning areas around stations, with very little empirical justification—more on this later.

A less used approach, the quadratic functional form, is specified such that the linear distance term is squared and both included in analysis. It has the distinct advantage of pinpointing the break point in the transit station distance curve.

In the context of rail transit, the concern is that rail stations themselves can be nuisances such that real estate values and rents may be dampened very near them. As Nelson and McClesky theorize [**11**], the market capitalizes both positive amenity effects of rail station proximity as well as negative amenity effects, such as those associated with noise, such as dispatching broadcasts at station platforms, and congestion, such as when vehicles use park and ride lots during peak hours [**12**]. So long as positive amenity effects outweigh negative ones, the bid rent gradient will be sloping downward and away from rail transit stations. In theory, however, it is possible for negative amenity effects to outweigh positive ones. These interactions are shown in Figure 1, described as follows:

> The line R^a shows the land rent (R) curve with full amenity (“a” for positive amenity) value from a rail transit station, u_0, outward to a point, u_1, where the amenity effects of rail transit proximity disappear, beyond which the overall market rent, unaffected by the presence of the rail transit station, R^m is revealed.

Negative effects of rail transit stations are shown in line R^n (“n” for negative amenity). As distance from the rail station increases, the negative amenity effects are reduced until they become zero at u^1.

Positive and negative amenity effects interact in the market leading to overall positive or negative bid rent curves with respect to distance from rail transit stations to u_1. Line $R^a + R^n{}_1$is revealed where overall positive amenity effects outweigh negative ones. Line $R^a + R^n{}_2$is revealed where overall negative amenity effects outweigh positive ones. Overall effects disappear at u_1 beyond which market rent, R^m, in the absence of positive and negative amenity is revealed.

With a quadratic analytic approach, estimates of the revealed bid rent gradients with respect to distance from rail transit stations may not detect the interaction between positive and negative amenity effects. In our view, this requires a model wherein the distance effects of rail transit stations are specified using the quadratic functional form. The first term, linear, reveals the strongest of the two influences, positive or negative. In cases where value is affected negatively by such sites as landfills, the linear term would be expected to have a negative association with respect to landfill distance while the second term would be positive so that after some distance, u_1, the negative effect is offset [**13**]. In the case of rail transit stations, theory suggests there would be an overall positive amenity effect with respect to station distance—the first term—but it can be dampened by underlying negative amenities—the second term.

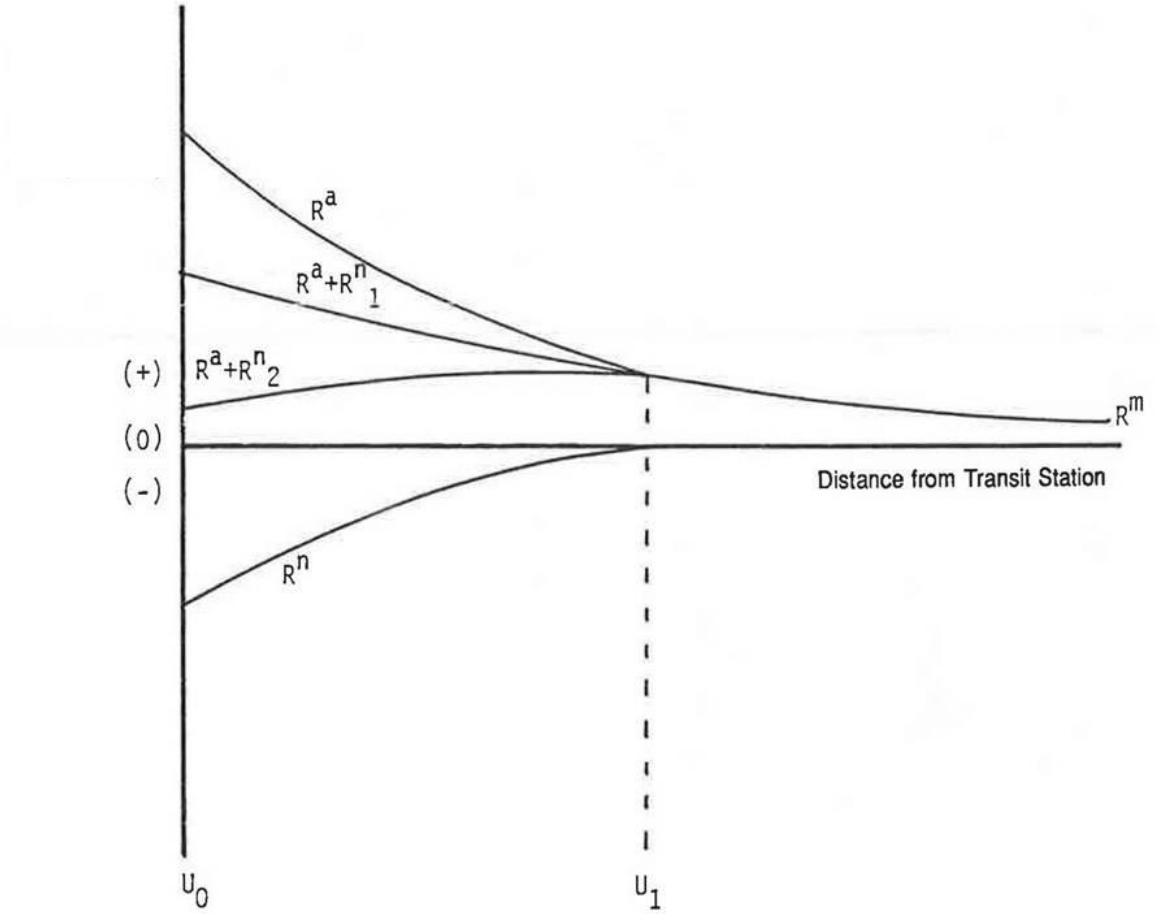

Figure 1

Positive Amenity (R^a) and Negative Amenity (R^n) influences of transition stations on proximate property values and rents

Source: Nelson and McClesky [**11**].

Mechanically, using a semi-log (log of the dependent variable) specification with the quadratic distance form means, for instance, that if the station linear distance coefficient is -5.00 but the quadratic transformation coefficient is 10.00, differentiating both terms results in -1.00. That is, the downward slope of the first term reaches minima at 1.00 mile then bends upward. For planners, this suggests that the market responds to transit station proximity to one mile away. Moreover, the equation can be mapped showing the decay in value with respect to distance. For instance, using the quadratic transformation, Nelson et al. [**14**] estimated that 75 percent of the office real estate rent lost with respect to distance from light rail stations occurred within 0.9 miles.

But quadratic functional forms may not be very useful either, especially if both signs are in the same direction (increasing or decreasing value at a faster rate with respect to distance). Even where signs are different, the smaller the second term relative to the first the flatter the slope. For example, if the second term above is 1.00, the minima is 10 miles which may not be very useful to planners crafting plans around stations.

Distance bands offer a middle ground between knowing whether and the extent to which real estate markets respond to transit stations usually within one quarter or one half mile [**9**]. But that assumes all relevant interactions useful for planners to know occur only within those narrow distance bands, and that those bands apply to all transit modes in all metropolitan areas. Following Hibberd et al., [**15**] this article expands on and applies the distance band concept, described in more detail below.

Study Area

Given that literature has not reported rigorous research into the relationship between streetcars and real estate values, or rent [**10**], we attempt to do so here. In particular, we apply the general model with various functional forms to the 14 streetcar systems that started operations in the United States since the 1990s. They include Atlanta, Charlotte, Cincinnati, Dallas, the District of Columbia (DC), Kansas City, Little Rock, New Orleans, Portland, Salt Lake, Seattle, Tacoma, Tampa, and Tucson. Where cities had existing heritage lines, such as New Orleans, we evaluate only the newly constructed line. Our analysis is limited to the central counties within which these streetcars operate—not all counties in their metropolitan areas. Specification details are reviewed next.

Specific Model and Data

With two exceptions noted below, we operationalize the general model vectors and functional forms here. Notably, we report the statistical association between rent per square foot for office, retail and multifamily properties with respect to streetcar station proximity using linear, semi-log, double log, quadratic and distance band functional forms, holding other factors constant.

R is the asking rent per square foot for property *i* reported by CoStar during 2017. These include all properties with space for rent from among office, retail, and multifamily real estate projects.[1] Analyses using linear and logged variations of the dependent variable are reported below. The linear functional form estimates the dollar change in rent with respect to a one unit

[1] Normally, statistical analysis is applied to samples of a universe. In this case, the study includes the universe of all properties reported by CoStar. As CoStar data come from real estate brokerages participating in its network, the data exclude non-participating brokerages or entities and properties not for rent such as owner-occupied properties.

change among individual independent variables such as median household income in the census block group within which the subject property is located.

By logging the dependent variable, the semi-log model allows for coefficients to be interpreted as the percent change in rent attributable to a one unit change in an independent variable such as median household income.

By logging the dependent variable and continuously measured independent variables, elasticities can be estimated show the percent change in rent associated with a one percentage change in median household income.

S is the bundle of structure attributes for property *i* reported by CoStar. This can include occupancy characteristics noted below. For all properties, this includes:

Gross leasable area in building square feet with the expectation that there will be a positive association between building area and rent because larger buildings presumably include more amenities than smaller ones.

Effective year built which is the later of the year of construction or the year of renovation as reported by CoStar with the expectation that newer buildings will command more rent than older ones.

Vacancy rate with the expectation that the higher the vacant rate the lower the rent. This may not always be the case however as high demand markets could result in high vacancy rates as owners may wait for higher paying tenants. Accordingly, signs may not be predictable especially considering that the study area is comprised of stable to rapidly growing central counties.

For office properties structure attributes also include binary variables indicating whether the building is considered *Class A* or *Class B* with the expectation that Class A rents will be higher than Class B which will be higher than Class C which is the referent building class. The number of *Floors* is also included with the expectation that the taller the building the higher the mean rent.

For retail, *Floors* are also included as a structure variable, as are the types of retail structures including *Power Center*, *Neighborhood Center*, *Community Center*, *Regional Mall*, *Lifestyle Center* and *Outlet Mall* all of which are expected to have a higher rent per square foot than *Strip Centers* which are the referent.

For multifamily facilities, structure attributes include whether the buildings are classified by CoStar as *High Rise* (15 or more floors), *Mid Rise* (four to 14 floors) or *Garden Apartments* (one to three floors in a complex of four or more buildings) all of which are expected to command higher rents per square foot than *Low Rise* structures (one to three floors in complex of three or fewer buildings), the referent.

Multifamily also includes occupancy restrictions, notably *Subsidized*, *Senior* or *Student* housing with *Market Rate* housing being the referent. The expectation is that relative to Market Rate multifamily units, rents for Subsidized and Student housing will be lower but rents for Senior housing will be higher.

The **SES** vector is comprised of two variables. The first is *Median Household Income* from the five year sample of the 2016 American Community Survey (ACS) for the block group within which a CoStar property is located, for which a positive association is expected with respect to rent [**16**] The second is the Number of Households in the block group also from the ACS where the expectation is the larger the number the higher the rent presumably because of improved accessibility to workers [**17**].

The attributes for the **P** vector are missing because resources did not allow us to identify planning and zoning conditions applied to the nearly 20,000 properties in our data base. We also attempted to create a variable representing the **U** vector but were unsuccessful with calibration. The attempt was patterned after Ewing and Hamidi's [**18**] entropy variable in which an index of land use mix is calculated. Data were not available to do this at the block group level for the study area. Adding these two vectors will be attempted in future research.

We divide the **L** vector into two location *controls* and the treatment, being streetcar station proximity. The first location control is *Distance from Downtown* for which a negative association is expected based on the AMM theory. Using Google Earth, we identified the central most point of each downtown. The second location control is *Distance from Freeway* which is defined as the nearest freeway or expressway ramp. Again, based on AMM, a negative association is expected.

The *treatment* **L** variable is distance from the nearest streetcar station done in two ways. The first is straight line distance of the subject property to the nearest streetcar station: *Distance from Streetcar*. This is a continuously measured linear variable for the linear and semi-log models, and its natural log for the double-log model. For the quadratic model, both the linear and quadratic terms are used in the same question.

The other treatment variable is a series of distance band, **DB** defined as the location of the subject property within one-eighth mile distance bands of the nearest streetcar stop to two miles. The two mile distance was used to assure a maximum reasonable distance to estimate distance band effects based on work by Nelson et al. **[19]** for Dallas office rental market light rail transit effects (about 1.75 miles) and Petheram et al. [**20**] for the Salt Lake County multifamily building light rail transit assessed value effects (about 1.25 miles). In the equations, for instance, DB >0.125-<=0.250 mile

means property *i* is in the distance band that is greater than 0.125 miles but less than or equal to 0.250 miles from the nearest street car transit station.

A measurement refinement that will be considered in future work is calculating the network travel distance, rather than straight line.

The **M** vector is comprised of the individual central counties within which the streetcar system of central cities operates. They include Atlanta, Charlotte, Cincinnati, Dallas, DC, Kansas City, New Orleans, Portland, Salt Lake, Seattle, Tacoma, Tampa, and Tucson with the referent being Little Rock.

Table 1 reports the mean statistics for all variables.

Our models include many times more data than used in most prior studies [**9**]. While we have no a priori expectations of goodness of fit outcomes, literature suggests that ordinary least squares hedonic (regression) analysis can explain between about one fifth to about three quarters of the variation in the observed rent for the properties [**9**].

Nonetheless, we recognize that future work can benefit from further refinements. A key refinement is to use network rather than Euclidian distance measures in future calibration of distance bands. Though we believe the models are robust, spatial statistical methods will be applied to future work to control for local dependence and the validity of model results.

We present results next followed by implications for transit and land use planning.

Table 1
Variables Means

Variables	Office Mean	Retail Mean	Multifamily Mean
Dependent Variable			
Rent per Square Foot, per year	$22.58	$19.94	$17.16
Structure Controls			
Gross Leasable Area, square feet	83,582	24,495	108,919
Effective Year Built	1990	1982	1977
Vacancy Rate	28%	19%	14%
Class A Office	20%		
Class B Office	54%		
Class C (referent)	26%		
Floors	4.62		
Power Center		2%	
Neighborhood Center		22%	
Community Center		7%	
Regional Mall		1%	
Lifestyle Center		1%	
Outlet Mall		1%	
Strip Center (referent)		66%	
High Rise			1%
Mid Rise			21%
Garden Apartments			37%
Low Rise (referent)			41%
Subsidized			5%
Senior			4%
Student			1%
Market Rate (referent)			90%
Demographic Controls			
Median Household Income	$66,727	$58,448	$52,702
Mean Block Group Households	782	722	761
Location Controls			
Distance from Downtown, feet	43,394	49,023	38,987
Distance from Freeway, feet	7,531	11,405	3,123

Streetcar Proximity			
Distance from Streetcar Stop, feet	35,756	40,786	11,427
<= 0.125 mile	5%	3%	8%
>0.125-<=0.250 mile	4%	1%	5%
>0.250-<=0.375 mile	3%	1%	4%
>0.375-<=0.500 mile	2%	1%	4%
>0.500-<=0.625 mile	1%	1%	4%
>0.625-<=0.750 mile	1%	1%	5%
>0.750-<=0.875 mile	1%	1%	4%
>0.875-<=1.000 mile	1%	1%	3%
>1.000-<=1.125 mile	1%	1%	3%
>1.125-<=1.250 mile	1%	1%	3%
>1.250-<=1.375 mile	1%	1%	3%
>1.375-<=1.500 mile	1%	1%	3%
>1.500-<=1.625 mile	1%	1%	3%
>1.625-<=1.750 mile	1%	1%	2%
>1.750-<=1.875 mile	1%	1%	3%
<=2.000 mile	1%	1%	2%
> 2.000 mile (referent)	74%	82%	41%
Metropolitan Areas Controls			
Atlanta	11%	7%	7%
Charlotte	5%	4%	5%
Cincinnati	8%	7%	6%
Dallas	18%	19%	14%
DC	9%	5%	8%
Kansas City	3%	4%	4%
New Orleans	1%	1%	1%
Portland	5%	3%	11%
Salt Lake	7%	1%	3%
Seattle	11%	11%	22%
Tacoma	4%	4%	6%
Tampa	10%	9%	5%
Tucson	7%	18%	6%
Little Rock (referent)	1%	7%	2%

RESULTS AND DISCUSSION

Tables 2, 3 and 4 report regression results for the five equations comprising the functional forms used in this analysis, for office, retail and multifamily properties respectively. Correlation matrices that are not reported for brevity do not reveal problematic collinearities between them. Performance measures are reasonable. Notably, the coefficients of determination (R^2) are within expectations of prior literature [**9**]. Data for the **P** and **U** vectors, and perhaps more refined property data may improve R^2 but given the lack of collinearity especially among the **L** and **P** variables, improvements will not change central tendencies.

Coefficients in bold are significant at the 0.05 or better level of the two-tailed t-test, since directions of association are predicted. This excludes **M** vector controls for metropolitan areas since there is no per se prediction of association; the only role of this vector is to control for nuances of individual metropolitan areas relative to others. Also not highlighted are those **DB** coefficients that are significant with or without the correct sign beyond the first insignificant **DB**. This provides for a conservative estimate of the minimum distance from streetcar stations where rent premiums dissipate.

For the most part, all control variables with significant coefficients have the correct signs and reasonable magnitudes. Notably, *Distance from Downtown* variables in all models are all significant and have the correct signs, confirming the AMM expectation for declining values with respect to downtown distance. The *Distance from Freeway* variable is decidedly less robust, however, as it is significant in only about half the equations though with the correct signs. In all cases, however, the slopes are very flat suggesting rents change scant few pennies per mile away from freeways. One reason may be the ubiquitous nature of freeway access across most metropolitan areas. We will not comment on the other control variables them for brevity, preferring to highlight spatially related streetcar distance results and implications.

The linear and semi-log equations do not show insignificant associations between rent and streetcar station distance in the office and retail models, though they are significant in the multifamily model albeit with the incorrect sign in the linear model. The Distance from Streetcar variable is significant with the correct sign in the office and retail double log models. In the office mode, for instance, a one percent increase in the mean distance from a streetcar station is associated with a one hundredth of one percent drop in mean rent per square foot—about 23 cents for every roughly 400 feet away which is not trivial. For retail it is higher at about 66 cents per square foot for every 400 feet away. Not only is the double log coefficient for multifamily insignificant, it is also very small, being about nine cents per square foot for about every 100 feet away—which at 400 feet would be a reduction of about 36 cents per square foot.

Results for the quadratic equation are interesting for the retail and multifamily models. Differentiating the linear and quadratic terms (and dividing by 5,280 feet in a mile), rents fall per square foot to 7.45 miles for retail properties and 1.99 miles for multifamily. For office it would be 4.29 miles if the linear term was significant though it had the correct sign.

In all four equations, the study areas are quite large (whole central counties) with mean distances to downtown ranging around eight miles. Moreover, except for the multifamily cases, 74 percent and 82 percent of the office and retail cases are beyond two miles from streetcar stations. In effect, the statistical may understate market responsiveness close to stations because the analysis is spread across large areas. One solution is to limit the analysis to just cases within five miles, or two miles, or some other distance around streetcar stations.

The distance band (DB) equations allow the relationship between rents and distance from streetcar stations to be more accurately estimated, because each band is treated as its own variable controlling for all others. Using this approach, we find significant associations between rent and streetcar station distance up to 0.500 mile for office properties, 0.875 mile for retail properties, and 1.000 mile for multifamily property.

For office properties, the DB rent coefficients are about the same to 0.375 mile—suggesting a 5.5 percent to 7.0 percent rent premium within each band, but rising to about 10 percent and the 0.375-0.500 DB. In other words, in the first 0.375 mile, there is roughly a $1.50 premium per square foot but in the last DB it rises to more than $2.00. Distance band coefficients are nearly all insignificant farther away. We speculate on the reason for this later.

For retail properties, there is roughly a 20 percent premium above the mean for being within any of the DBs out to 0.875 mile, beyond which DB coefficients are all insignificant. The rent premium is about $4.00 per square foot. We speculate on why the retail rent premium with respect to streetcar station distance is essentially constant to 0.875 mile but not beyond.

In contrast, coefficients for multifamily properties decline mostly steadily from the innermost DB to 1.000 mile. Over these eight distance bands, mean rent premiums fall from about $3.50 to about 66 cents per square foot per year. Notably, multifamily rent premiums are higher than those for office properties to about one 0.375 mile away where the office rent premium with respect to streetcar station distance dominates. Though retail and multifamily rent premiums are about the same to 0.375 mile, we suspect in areas close to streetcar stations that retail activities may occupy the first level of a multilevel building where residential activities occur on the upper levels.

The rent premiums based on distance bands for office, retail and multifamily properties are illustrated in figure 2.

These insights are expanded in the last part of the article where we explore transit and land use planning implications.

Table 2
Office Rent Premiums with Respect to Streetcar Station Proximity by Functional Form

Variables	**Linear**	**Semi-log**	**Double Log**	**Quadratic**	**Distance Band**
Constant	5.326	2.315	-1.388	2.331	2.338
Structure Controls					
Gross Leasable Area, Ln	-2.070E-006	**-1.771E-007**	**0.291**	**-1.661E-007**	**-1.531E-007**
Class A Office	**7.931**	**0.372**	**0.103**	**0.374**	**0.377**
Class B Office	**1.699**	**0.126**	-0.003	**0.129**	**0.129**
Floors	0.055	**0.005**	**0.069**	**0.005**	**0.004**
Effective Year Built, Ln	**0.005**	**0.000**	**0.425**	**0.000**	0.000E+000
Vacancy Rate, Ln	**-0.014**	**-0.001**	**-0.004**	**-0.001**	**-0.001**
Demographic Controls					
Median HH Income, Ln	**3.610E-005**	**1.543E-006**	**0.106**	**1.558E-006**	**1.581E-006**
Households, Ln	**0.001**	**4.565E-005**	**0.023**	**4.257E-005**	**4.133E-005**
Location Controls					
Distance from Downtown, Ln	**-6.856E-005**	**-3.355E-006**	**-0.035**	**-3.354E-006**	**-2.059E-006**
Distance from Freeway, Ln	4.838E-006	9.346E-008	**-0.008**	4.530E-007	4.777E-007
Streetcar Proximity					
Distance from Streetcar, Ln	9.638E-006	9.365E-007	**-0.010**	-7.118E-007	
Distance from Streetcar Squared				**1.570E-011**	
DB <= 0.125 mile					**0.057**
DB >0.125-<=0.250 mile					**0.072**
DB >0.250-<=0.375 mile					**0.056**
DB >0.375-<=0.500 mile					**0.101**
DB >0.500-<=0.625 mile					0.033
DB >0.625-<=0.750 mile					0.003
DB >0.750-<=0.875 mile					0.057
DB >0.875-<=1.000 mile					0.011
DB >1.000-<=1.125 mile					0.061

DB >1.125-<=1.250 mile					0.072
DB >1.250-<=1.375 mile					-0.063
DB >1.375-<=1.500 mile					0.026
DB >1.500-<=1.625 mile					0.092
DB >1.625-<=1.750 mile					0.017
DB >1.750-<=1.875 mile					0.089
<=2.000 mile					0.144
Metropolitan Areas Controls					
Atlanta	5.367	0.266	0.219	0.253	0.262
Charlotte	-2.887	-0.106	-0.141	-0.103	-0.109
Cincinnati	2.816	0.219	0.224	0.218	0.218
Dallas	1.515	0.141	0.115	0.147	0.136
DC	23.031	0.814	0.787	0.803	0.810
Kansas City	-0.557	0.035	-0.006	0.030	0.026
New Orleans	-0.330	0.065	0.024	0.051	0.046
Portland	3.787	0.265	0.245	0.252	0.246
Salt Lake	1.237	0.103	0.075	0.104	0.100
Seattle	8.465	0.439	0.406	0.435	0.433
Tacoma	10.266	0.521	0.209	0.518	0.373
Tampa	2.748	0.187	0.203	0.189	0.188
Tucson	1.169	0.140	0.179	0.130	0.130
Model Performance					
Cases	6,036	6036	5962	6036	6036
Adjusted R2	0.410	0.521	0.510	0.522	0.523
Standard Error	10.3158026	0.3134173	0.312369	0.3130243	0.3127103
F-ratio	175.943	274.285	259.92	264.619	

Table 3
Retail Rent Premiums with Respect to Streetcar Station Proximity by Functional Form

Variables	**Linear**	**Semi-log**	**Double Log**	**Quadratic**	**Distance Band**
Constant	-3.903	1.512	-0.467	1.540	1.403
Structure Controls					
Gross Leasable Area, Ln	**-1.471E-005**	**-1.348E-006**	**-0.075**	**-1.347E-006**	**-1.364E-006**
Floors, Ln	**0.009**	**0.001**	**0.078**	**0.001**	**0.001**
Effective Year Built, Ln	**0.010**	**0.001**	**0.183**	**0.001**	**0.001**
Vacancy Rate, Ln	-0.010	**-0.001**	**-0.005**	**-0.001**	**-0.001**
Structure Type					
Power Center	4.809	0.268	0.364	0.298	0.281
Neighborhood Center	0.142	0.021	0.105	0.038	0.030
Community Center	2.282	0.113	0.183	0.132	0.129
Regional Mall	12.261	0.475	0.477	0.512	0.476
Lifestyle Center	4.279	0.273	0.332	0.280	0.262
Outlet Mall	19.908	1.234	1.154	1.279	1.249
Demographic Controls					
Median HH Income, Ln	**9.313E-005**	**4.047E-006**	**0.267**	**4.070E-006**	**4.070E-006**
Households, Ln	**0.002**	**9.881E-005**	**0.088**	**9.738E-005**	**8.732E-005**
Location Controls					
Distance from Downtown, Ln	**-0.000**	**-3.664E-006**	**-0.046**	**-4.059E-006**	**-2.025E-006**
Distance from Freeway, Ln	-1.770E-006	7.822E-007	**-0.014**	1.754E-006	9.365E-007
Streetcar Proximity					
Distance from Streetcar, Ln	4.344E-005	9.843E-007	**-0.033**	**-3.257E-006**	
Distance from Streetcar Squared				**4.139E-011**	
DB <= 0.125 mile					**0.195**
DB >0.125-<=0.250 mile					**0.221**
DB >0.250-<=0.375 mile					**0.155**
DB >0.375-<=0.500 mile					**0.211**

DB >0.500-<=0.625 mile					**0.141**
DB >0.625-<=0.750 mile					**0.129**
DB >0.750-<=0.875 mile					**0.222**
DB >0.875-<=1.000 mile					-0.076
DB >1.000-<=1.125 mile					0.061
DB >1.125-<=1.250 mile					-0.086
DB >1.250-<=1.375 mile					-0.048
DB >1.375-<=1.500 mile					0.096
DB >1.500-<=1.625 mile					-0.129
DB >1.625-<=1.750 mile					-0.042
DB >1.750-<=1.875 mile					0.028
<=2.000 mile					0.053
Metropolitan Areas Controls					
Atlanta	0.277	0.077	0.068	0.030	0.064
Charlotte	-3.862	-0.172	-0.172	-0.157	-0.172
Cincinnati	0.776	0.140	0.123	0.134	0.136
Dallas	-1.009	0.015	0.011	0.026	0.004
DC	19.126	0.688	0.583	0.651	0.707
Kansas City	-4.043	-0.127	-0.166	-0.130	-0.128
New Orleans	1.478	0.198	0.155	0.153	0.134
Portland	-0.169	0.149	0.069	0.120	0.121
Salt Lake	0.383	0.107	0.094	0.102	0.087
Seattle	6.255	0.368	0.301	0.346	0.352
Tacoma	0.120	0.490	0.173	0.522	0.304
Tampa	-0.833	0.059	0.062	0.054	0.057
Tucson	-2.916	-0.074	-0.003	-0.103	-0.069
Model Performance					
Cases	3002	3002	3011	3002	3002
Adjusted R2	0.344	0.350	0.354	0.355	0.355
Standard Error	10.4698837	0.4198923	0.4200266	0.4180765	0.417764
F-ratio	57.272	58.53	59.866	57.93	

Table 4
Multifamily Rent Premiums with Respect to Streetcar Station Proximity by Functional Form

Variables	Linear	Semi-log	Double Log	Quadratic	Distance Band
Constant	-3.158	-2.236E+000	-21.707	-2.311E+000	-2.691
Structure Controls					
Gross Leasable Area, Ln	**1.037E-007**	**1.725E-007**	**0.074**	**1.798E-007**	**1.681E-007**
Average Unit Size, Ln	**-1.925E-005**	**-3.316E-005**	**-0.557**	**-3.288E-005**	**-3.299E-005**
Effective Year Built, Ln	**0.002**	**0.001**	**3.045**	**0.001**	**0.001**
Vacancy Rate, Ln	**0.007**	**0.003**	**0.008**	**0.003**	**0.003**
High Rise	**0.570**	**0.344**	**0.205**	**0.328**	**0.294**
Mid Rise	**0.413**	**0.246**	**0.113**	**0.242**	**0.230**
Garden Apartments	**0.040**	**0.021**	**-0.037**	**0.028**	**0.034**
Occupancy Controls					
Subsidized	**-0.160**	**-0.061**	**-0.089**	**-0.062**	**-0.063**
Senior	**0.193**	**6.800E-002**	**-0.046**	**7.300E-002**	**0.072**
Student	**-0.117**	**-0.231**	**-0.183**	**-0.238**	**-0.252**
Demographic Controls					
Median HH Income, Ln	**4.861E-006**	**3.031E-006**	**0.200**	**3.052E-006**	**3.003E-006**
Households, Ln	**9.922E-005**	**5.108E-005**	**0.024**	**4.876E-005**	**4.122E-005**
Location Controls					
Distance from Downtown, Ln	**-1.015E-005**	**-5.175E-006**	**-0.098**	**-3.900E-006**	**-1.717E-006**
Distance from Freeway, Ln	**-7.612E-006**	**-3.412E-006**	0.007	**-5.052E-006**	-6.691E-007
Streetcar Proximity					
Distance from Streetcar, Ln	**1.486E-005**	**-6.166E-006**	-0.005	**-3.857E-006**	
Distance from Streetcar Squared				**1.839E-010**	
DB <= 0.125 mile					**0.204**
DB >0.125-<=0.250 mile					**0.161**
DB >0.250-<=0.375 mile					**0.141**
DB >0.375-<=0.500 mile					**0.138**

DB >0.500-<=0.625 mile					**0.118**
DB >0.625-<=0.750 mile					**0.074**
DB >0.750-<=0.875 mile					**0.096**
DB >0.875-<=1.000 mile					**0.039**
DB >1.000-<=1.125 mile					0.017
DB >1.125-<=1.250 mile					0.009
DB >1.250-<=1.375 mile					0.021
DB >1.375-<=1.500 mile					-0.029
DB >1.500-<=1.625 mile					0.008
DB >1.625-<=1.750 mile					0.001
DB >1.750-<=1.875 mile					-0.034
<=2.000 mile					-0.008
Metropolitan Areas Controls					
Atlanta	0.277	0.272	0.314	0.271	0.257
Charlotte	0.179	0.195	0.195	0.197	0.186
Cincinnati	0.158	0.119	0.125	0.125	0.117
Dallas	0.439	0.395	0.354	0.393	0.359
DC	1.150	0.753	0.726	0.751	0.750
Kansas City	0.156	0.144	0.146	0.143	0.113
New Orleans	0.403	0.364	0.340	0.345	0.286
Portland	0.619	0.510	0.470	0.505	0.472
Salt Lake	0.297	0.288	0.249	0.283	0.264
Seattle	0.991	0.729	0.675	0.724	0.695
Tacoma	1.144	0.809	0.587	0.668	0.648
Tampa	0.419	0.363	0.348	0.367	0.349
Tucson	0.128	0.126	0.111	0.189	0.175
Model Performance					
Cases	13,560	13,560	13560	13,560	13,560
Adjusted R2	0.541	0.590	0.693	0.594	0.601
Standard Error	0.4991607	0.2855292	0.2471617	0.284298	0.2817922
F-ratio	571.755	699.193	1094.792	685.027	

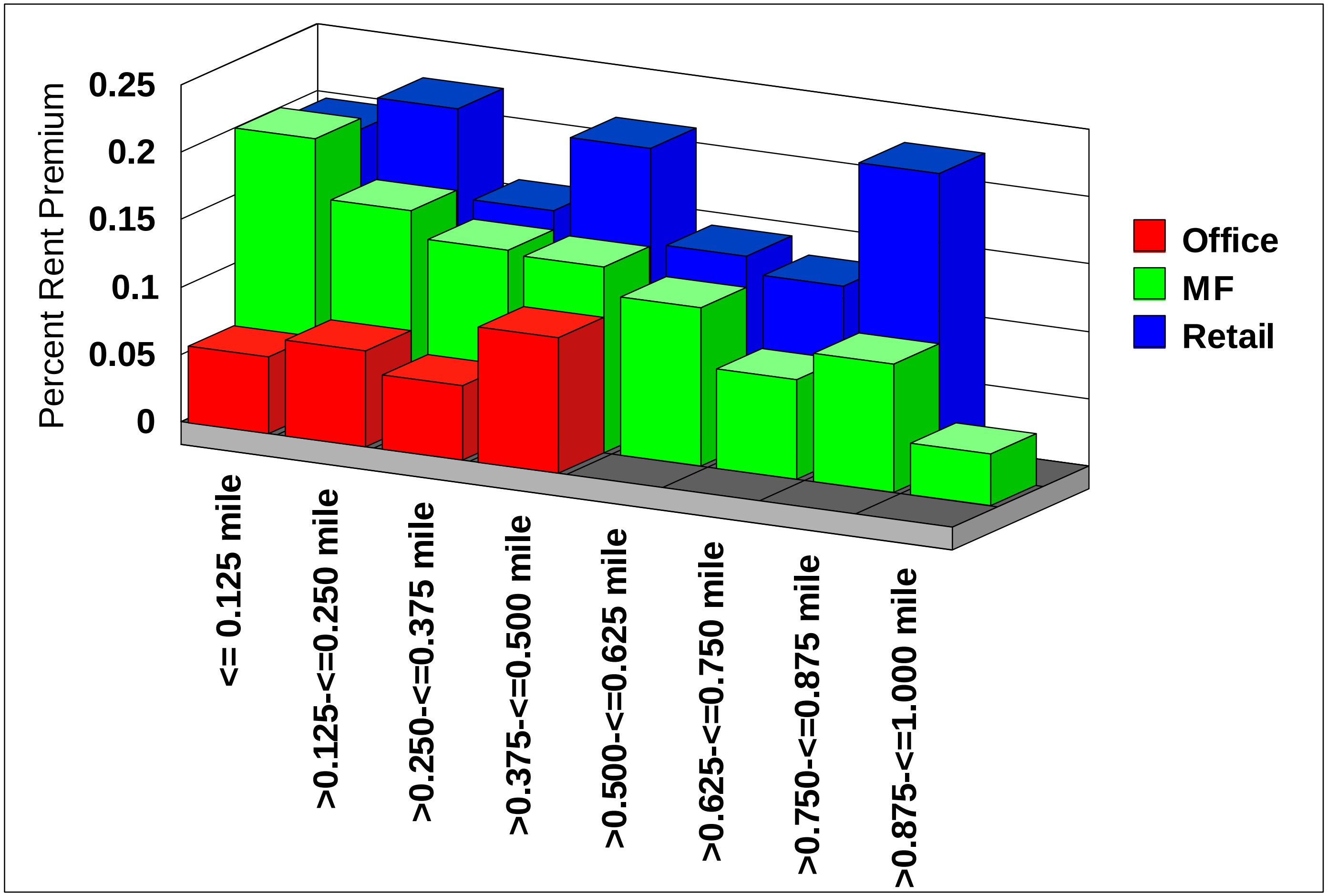

Figure 2

Percent rent change by distance band from streetcar stations. (MF means multifamily.)

IMPLICATIONS FOR TRANSIT AND LAND USE PLANNING

This article may offer two main lessons for transit and land use planning. First of all, when evaluating transit systems for their effect on markets, the functional form of the model specification matters. Second, understanding how different land uses react in the market to different distances from transit stations also matters.

Though analysts tend to have their preferred analytic methodologies when they assess transit system impacts on jobs, housing, land uses, and real estate—many no doubt preferring the AMM semi-log or double log approaches—it may be that fine-grained distance band approaches are more informative for planning purposes. Unfortunately, distance band based studies in the past often used simple one-half mile [**21**] or one-half and one mile [**10**] buffers to assess differential effects of transit on development outcomes. In this study, one-eighth mile distance bands were used. This approach has the effect of creating unique, small area buffers around transit stations so that differences between small distances can be revealed. In contrast, analyses with large study areas may use functional forms that by design hide important, albeit subtle market effects that occur very close to stations with measurable effects up to a mile away [**20**]. Not that distance band based spatial analyses should be the only choice of functional forms but at least more effort should be made to apply this approach in future studies.

More practically are the implications of this study on streetcar planning, especially land use planning around streetcar stations. For one thing, we are not aware of any transit studies assessing differential real estate market effects with respect to small incremental distances from, stations. This would seem especially important in the case of streetcars because (a) those systems tend to serve more highly urbanized areas than other forms of fixed guideway transit systems and (b) there are simply no studies evaluating real estate market responsiveness to multiple land uses in the same area.

A key insight from this study may that multifamily rental land uses appear to outbid office space near streetcar stations. Offices could be pushed away from streetcar stations but if they still need access to close-in locations where do they go? Because the multifamily rental premium declines rapidly as seen in Table 4 and illustrated in Figure 2, it may be that offices do not need to move very far: perhaps to about one half mile away. For its part, retail serves both residential and nonresidential needs so it benefits from the competition of both those land uses to roughly the area between where the office and multifamily rent premiums dissipate beyond significance. Certainly all three land use types can also occupy the same space in mixed use developments.

Modern streetcars in America are less than 20 years old and most are less than 10 years old. There is much to learn about how the market responds to them. Continually monitoring how streetcars add value to the real estate market, such as through rents, can help refine streetcar system and associated land use planning in the decades to come. Moreover, the lessons learned from this study may be applied to future analyses relating to how other types of transit modes influence the real estate market.

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