The effect of urban trees on the rental price of single-family homes in Portland, Oregon

Geoffrey H. Donovan (corresponding author)
USDA Forest Service PNW Research Station
620 SW Main, Suite 400
Portland, OR 97205
Tel: (503) 808-2043
Fax: (503) 808-2033
gdonovan@fs.fed.us

David T. Butry
National Institute of Standards and Technology
100 Bureau Drive, Mailstop 8603
Gaithersburg, MD 20899-8603
Tel: (301) 975-6136
david.butry@nist.gov

ABSTRACT: Few studies have estimated the effect of environmental amenities on the rental price of houses. We address this gap in the literature by quantifying the effect of urban trees on the rental price of single-family homes in Portland, Oregon. We found that an additional tree on a house's lot increased monthly rent by $5.62, and a tree in the public right of way increased rent by $21.00. These results are consistent with a previous hedonic analysis of the effects of trees on the sales price of homes in Portland, which suggests that homeowners and renters place similar values on urban trees.

KEYWORDS: hedonic, Portland, rental price, urban trees

Introduction

Numerous studies have used the hedonic price method to estimate the effect of environmental amenities (Garrod and Willis, 1992; Boyle et al., 1999; Leggett and Bockstael, 2000; Kim et al., 2003; Mansfield et al., 2005) and disamenities (Espey and Lopez, 2000; Bin and Polasky, 2004; Loomis, 2004; Donovan et al., 2007) on the sales price of houses. However, far fewer studies have estimated the effect of environmental amenities or disamenities on the rental price of houses. Understanding how residential rental prices respond to environmental goods is an important question as one-third of the U.S. population rent their homes (Census, 2007). Furthermore, there are significant demographic differences between home renters and homeowners, and demographics have been shown to influence environmental preferences (Kaplan and Talbot, 1988; Johnson et al., 2004). Therefore, it would be inappropriate to only use results from sales-price hedonic studies to inform environmental policy.

The focus of our study is the effect of urban trees on the rental price of single-family homes in Portland, Oregon. A previous study in Portland quantified the effect of urban trees on the sales price of single-family homes (Donovan and Butry, 2010). Therefore, the current study offers a unique opportunity to compare the effect of an environmental good on the sales and rental prices of single-family homes in the same city.

Numerous studies in the real estate literature have used the hedonic price method to examine the effect of attributes of a house and its neighborhood on rental price (Sirmans et al., 1989; Sirmans and Benjamin, 1991; Des Rosiers and Theriault, 1996; Benjamin et al., 2000). However, we could find only one study that has focused on the effect of environmental amenities. Baranzini and Ramirez (2005) examined the effect of noise on rents in Geneva. They found that noise, in particular airport noise, reduced the rental price of both privately and publicly owned apartments. In addition, they found that the marginal effect of noise declined as the level of background noise increased.

No rental-hedonic studies have quantified the effect of urban trees, and few sales-price hedonic studies have done so. Using Multiple Listing Service photographs of houses, Anderson and Cordell (1988) quantified the effect of front-yard trees on the sales price of homes in Athens, Georgia. They found that a front-yard tree added $422 (1.1 %) to the sales price of a house. Culp (2008) examined the effect of trees on the sales price and time on the market of homes in Lehigh County, Pennsylvania. He found that trees overhanging one side of a house reduced sales price, whereas mature trees on a house's lot increased sales price. Having trees on three sides of a house reduced time on the market as did large trees behind a house although to a lesser degree. Donovan and Butry (2010) quantified the effect of street trees (trees in the green strip between sidewalk and the road) the in Portland, Oregon. They found that a street tree added $7130 to the sales price of the house it fronts, and a total of $12 828 to the sales price of houses within 100 ft (30.5 m). There were, on average, 7.6 houses within 100 ft (30.5 m) of a street tree (from now on, we refer to Donovan and Butry 2010 as D&B).

Data and study area

Portland is the largest city in Oregon, with an estimated population of 537 000 in 2006 (Census, 2006). Currently, 26 % of the city is covered by tree canopy, although a goal of the city is to increase this to 33 %, which will require planting approximately 415 000 trees (Karps, 2007).

Sales-price hedonic studies often don't involve primary data collection, so analysts don't decide on a sample size in advance. Rather they include all sales that satisfy certain criteria: sales that occurred in a particular geographic area in a specified time frame, for example. We did not have access to secondary data on rental prices. Therefore, we collected data on the rental price of homes from the website

Craigslist. Before starting data collection, we decided on a sample size of 1000 single-family detached homes (no apartments, condominiums, row houses, or duplexes). We limited the study to single-family homes for two reasons. First, D&B only studied single-family homes, and we wanted the results of the two studies to be comparable. Second, there are practical difficulties measuring trees around apartments and condominiums. Google Earth, which we used to measure trees, can locate the address of condominium or apartment but not the specific unit number, so we would have been unable to determine a unit's location within a condominium or apartment complex.

We began collecting data on October 23, 2009, including every house that met our selection criteria. In addition, we only included houses that listed an address (very few listings failed to provide an address). It took until January 14, 2010, to collect 1000 observations. We obtained data on the physical attributes of these houses (size, number of bedrooms, type of heating, etc.) from Multnomah County Tax Assessor's Office and crime data from the Portland Police Bureau (Table 1).

Table 1 here

Unlike house sales, data on house rentals are not centrally collected. As a practical matter, this makes collecting data more time consuming, but it also means that we don't know whether the sample we collected is representative of all rentals in Portland. For example, it's possible that rentals advertised on Craigslist are more expensive than those advertised elsewhere. However, if our sample were systematically biased, this bias might be revealed in the spatial distribution of observations (clusters in more expensive neighborhoods, for example). Figure 1 doesn't exhibit any obvious spatial patterns, which is encouraging but certainly doesn't rule out the possibility of bias. In the methods section we detail formal tests to detect spatial patterns. Nonetheless, the possibility remains that our sample is biased. Therefore, strictly speaking, results of our analysis only apply to rentals advertised on Craigslist.

We geo-coded each house by matching addresses to the Regional Land Information System Database, which is maintained by Metro, a tri-county planning body. This process of address matching reduced the sample size to 985.

In Portland, as in many other cities, more desirable neighborhoods often have more or larger trees. Failing to control for neighborhood could, therefore, lead to biased coefficients on tree variables. We controlled for neighborhood in two ways. First, we accounted for neighborhood characteristics: crime rates and distance to parks. Second, we directly controlled for neighborhood using a continuous variable describing the distance from the centroid of a house's lot to Portland's city center (DISTANCE_TO_CITY_CENTER) and a series of dummy variables denoting a house's ZIP code. If a ZIP code had fewer than 20 observations, we combined it with a neighboring ZIP code (for example, ZIP_17_27 denotes a house in either the 97217 or 97227 ZIP code). Several ZIP codes in central Portland had fewer than 20 observations, so we created an aggregate dummy variable to account for these ZIP codes (ZIP_CENT). Tree cover varied significantly by ZIP code. For example, the mean number of street trees went from a low of 0.22 in ZIP code 97216 to a high of 1.46 in the combined ZIP codes 97212 and 97232.

In D&B, we measured a wide range of tree attributes including height, diameter, crown area, and measures of health and form. It wasn't possible to measure all these variables for trees on private property, so we restricted our analysis to street trees (we controlled for canopy cover on a house's lot using classified aerial imagery). However, we found that only the number of trees and their crown area influenced sales price, and both of these variables can be measured remotely using aerial photographs. Therefore, in our current study, we only collected data on number of trees and their crown area, and we did so for both street trees and trees on a house's lot. Data collection was done by hand using images from Google Earth. We treated a tree's crown as a circle and calculated its area based upon the average of two diagonal measurements. The crown of a tree often crossed property lines, but, in these cases, we did not divide up a tree's crown among different properties. Rather, we attributed a tree's entire crown to the property in which the tree's stem fell. This means that the LOT_CROWN_AREA variable does not include the crown area of trees from neighboring houses, even if that tree's crown overhangs the house in question. Sometimes determining where a tree's stem falls from aerial photographs was difficult. Google Earth's street view was useful at resolving much of this ambiguity, but sometimes we had to make judgments based on our past data-collection experience.

Methods

Since the original theoretical work of Rosen (Rosen, 1974), the hedonic price method has been used to estimate the value of a wide range of environmental goods. Sales price—or in our case monthly rental price—is regressed against characteristics of a house, its neighborhood, and the environmental good under study. Theory does not suggest a particular functional form for the hedonic equation, although most analysts do not use a simple linear form, because they do not believe that all characteristics of a house (area, for example) have a constant marginal effect on sales price or rent (Taylor, 2003). We used a semi-log functional form in which the natural log of monthly rent is regressed against the natural log of house area with all other variables represented linearly.

$$\ln(p) = \beta_0 + \beta_1 \ln(area) + \beta_x \mathbf{X} + e$$

where monthly rental price is denoted by *p*, *area* denotes the finished area of a house, **X** denotes a vector of house and neighbor characteristics (including variables describing trees), *e* is the error term, and β's denote coefficients to be estimated in the regression step. We experimented with a number of other non-linear functional forms, but the semi-log form had the best model fit. In addition, coefficients of interest were largely insensitive to functional form.

Model selection was done using iterative backward selection: variables were eliminated based on progressively lower p-value thresholds of 0.8, 0.6, and 0.2 (if one of a set of dummy variables—those describing ZIP codes, for example—passed a significance threshold, then we retained the entire set). Naïve backwards selection in the presence of multicollinearity can be problematic, and a variance-covariance matrix showed that several candidate variables were collinear. Therefore, the backwards selection process was somewhat iterative. We systematically reintroduced collinear variables to ensure that the final model specification wasn't influenced by the order in which variables were eliminated.

Results

Regression results are given in Table 2.

Table 2 here

Marginal effects were calculated with all independent variables set to their mean values. The marginal effects of continuous variables were estimated as incremental increases from these means. For example, the average number of bathrooms in the sample is 1.5. Increasing this number to 2.5 increases rent by $79.20. We calculated the marginal effects of dummy variables (categorical variables can't change marginally; we use the term marginal loosely to be consistent with the continuous variables) by setting a variable to zero and then to one.

The effects of house attributes (BATHS, BEDS, GARAGE, and LOG_SIZE) are consistent with economic theory and past hedonic studies. Economic theory does not suggest how the age of a house should affect its sales or rental price. However, the positive coefficient on AGE is consistent with D&B. However, in contrast to D&B—which found that LOT increased sales price—the size of a house's lot did not affect its rental price. This is not surprising, as renters may be less likely to invest time and money in a garden, given that they may be renting a house for a short time, and these investments typically cannot be recouped when they move.

The negative effect of CRIME is consistent with economic theory, but the effect of our other measure of neighborhood quality (DISTANCE_TO_PARK) was unexpected. We offer two possible explanations. First, although parks are generally viewed as a positive amenity, Troy and Grove (2008) found that in high-crime neighborhoods proximity to a park reduced the sales price of a house. Second, DISTANCE_TO_PARK may be correlated to an omitted, positive neighborhood amenity. For example, houses that are further away from parks may tend to be closer to shops or restaurants.

The effect of DISTANCE_TO_CITY_CENTER was expected and consistent with D&B. The effects of ZIP code dummy variables indicate that rents can vary significantly by neighborhood. ZIP code results are not directly comparable with D&B, because we created aggregate dummy variables, and because we were unable to use the same excluded ZIP-code dummy in both studies.

Of the tree variables evaluated, only NUMBER_OF_STREET_TREES and NUMBER_OF_LOT_TREES had a significant effect on rental price: $21.00 and $5.62 per month respectively. These marginal effects are not directly comparable to those in D&B, because the dependent variable is monthly rent, whereas in D&B the dependent variable was sales price. Therefore, to compare the effect of trees in the two models we calculated price elasticity with respect number of street trees. In D&B price elasticity was 0.0147 (95 % CI: 0.0106 to 0.0189) whereas in the current study it is 0.00938 (95 % CI: 0.003374 to 0.0150). Therefore, although rental-price elasticity is less than sales-price elasticity, the rental price point estimate is within the 95 % confidence bounds of the sales price point estimate.

Comparing elasticities is not the most intuitively appealing way to compare results. We can also compare our results to D&B by converting them from a stream of monthly benefits to a net-present value. However, this calculation requires us to assume a discount rate. There is an ongoing debate about the appropriate discount rate to use when calculating the net present value of a stream of environmental benefits. Legitimate objections could be raised to any discount rate we selected. Therefore, we take a different approach and solve for the discount rate that would equate a perpetual stream of monthly benefits of $21.00 and a lump sum of $7130 (the value of an additional street tree in D&B). The formula for the net present value of a perpetual stream of annual benefits is:

The discount rate that equates this expression is 3.5 %. Although this is no correct discount rate for evaluating the benefits of urban trees, we contend that this rate is within the range that a reasonable analyst would use. For example, Row et al. (1981) argue that the USDA Forest Service should use a 4 % discount rate to evaluate long-term investments.

To provide context for the comparison of our results with those from D&B, Table 3 compares the mean value of selected independent variables from the two studies.

Table 3 here

We found significant differences in three of the variables; however, only one of these variables, SIZE, was significant in both studies. Houses in D&B were, on average, larger than those in our sample. To quantify the effect of larger houses, we re-estimated the marginal effect of NUMBER_OF_STREET_TREES with SIZE set to its mean value from D&B. It increased the marginal value of a street tree from $21.00 to $22.14. This suggests that a difference in house size between the two studies does not jeopardize our conclusion that homeowners and renters place a similar value on street trees.

Spatial dependence

Spatial dependence is a statistical issue that commonly arises in hedonic-price models (Taylor, 2003; Donovan et al., 2007). Depending on the form it takes, spatial dependence can result in inefficient or biased coefficient estimates (Anselin and Hudak, 1992). We used a semivariogram, which compares model residuals across space, to check for possible presence of spatial dependence. This allowed us to quickly determine if further more complex testing were required, and it allowed us to do so without specifying a functional form for the spatial dependence (i.e., a spatial-weights matrix). Using a semivariogram to investigate spatial dependence is similar to using a residual plot to look for heteroscedasticity in that a visual inspection is used (they are graphed differently).

Figure 2 here

As Figure 2 shows, the model residuals don't demonstrate any obvious spatial patterns. However, as an additional precaution, we tested for the presence of spatial dependence using a Moran's I test (Anselin, 1988). This test requires the analyst to specify a spatial-weights matrix, which defines the spatial relationship between observations. A semivariogram is often useful in defining the nature and extent of these spatial relationships. However, in our case, model residuals didn't exhibit any clear spatial patterns. Therefore, we employed the two most commonly used spatial relationships—inverse distance and inverse distance squared—to define our spatial-weights matrices. In neither case did we find evidence of spatial dependence at the 10 % significance level. Therefore, we estimated model coefficients with ordinary least squares.

Discussion

We quantified the effect of urban trees on the rental price of single-family homes in Portland, Oregon. We found that an additional lot tree increased a house's monthly-rental price by $5.62, whereas an additional street tree increased rent by $21.00. There are a number of possible explanations for the differential effects of lot and street trees. Because they are directly in front of a house, street trees tend to be more visible than lot trees. Therefore, when a prospective tenant visits a house, street trees may have more curb appeal than lot trees. In addition, because they are on the property that a tenant will be renting, the maintenance requirements of a lot tree—raking up leaves, for example—may more readily come to mind.

There was no statistical difference in the price elasticity with respect to street trees between this study and D&B, which suggests that homeowners and renters place a similar value on street trees. This comparison also illustrates that people value the benefits that trees provide (beauty, shade, etc.) not the trees themselves. In consequence, not owning a tree is no impediment to enjoying the benefits that it provides. This distinction is important and often misunderstood. Many government agencies and non profits promote the benefits of trees. They often treat the positive effect that trees have on property values as a benefit. When viewed as a benefit and not as a measure of benefit, the property-price effect of trees could only be enjoyed by property owners. However, our results emphasize that the effect of trees on house price and rent is simply a reflection of the significant benefits that trees can provide to all urban residents.

In the introduction to this paper, we speculated that only using sales-price hedonic studies to inform environmental policy could be inappropriate, because renters may have different environmental preferences than home owners. In the case of urban trees in Portland, Oregon, this appears not to be the case. More research is needed to determine whether this similarity in environmental preferences extends beyond urban trees. If preferences are found to be comparable across a broader range of environmental goods, this would simplify the lives of economists and environmental-policy makers, as sales-price hedonic studies are simpler and cheaper to conduct.

Our study has several shortcomings. First, we only included single-family homes in our sample, which limits the applicability of our findings. Second, we used the rental price asked by landlords not the price paid by renters. One would expect the price asked by a landlord to be closely correlated with a renter's willingness to pay. Indeed, our results provide some support for this point of view. For example, the insignificance of the size of a house's lot suggests that our results reflect renters' not home owners' preferences. Nonetheless, our use of asking price is an additional source of uncertainty in our analysis. It is also possible that our sample is not representative of all single-family rentals in Portland. However, if the sample were biased, this bias would likely have a spatial component. For example, if the homes in our sample were systematically more expensive, this bias might manifest spatially, as some neighborhoods are more desirable and have higher rent. Figure 1 shows that our sample was drawn from all parts of the city. In addition, we found no evidence of spatial dependence in model residuals. The absence of spatial patterns in the distribution of observations and model residuals does not prove that our sample was not biased. Indeed, as data on rents in Portland are not systematically reported, we cannot dismiss the possibility of sample bias, and this should be considered when interpreting our results. Finally, we only measured the number of trees and their crown size. This was a pragmatic choice, as these were the only two tree variables that were significant in D&B, and both could be collected remotely, which allowed us to include lot trees as well as street trees in our analysis. However, it's possible that other tree attributes may influence rental price: species, for example. If we failed to account for other, significant tree characteristics, and these characteristics were correlated with the number and crown size of trees, then the coefficients on NUMBER_OF_LOT_TREES and NUMBER_OF_STREET_TREES could be inefficient or biased.

Despite these limitations, we believe our analysis provides unique insight into the benefits provided by urban trees. More generally, our results demonstrate that homeowners and renters may value environmental amenities similarly.

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Tables

TABLE 1

Variables Evaluated for Inclusion in the Rental-Hedonic Model

Variable	Definition
RENT	Monthly rent ($)
SIZE	Finished area of house (m^2)
LOT	Area of house's lot (m^2)
AGE	Age of house (base year 2010)
BEDS	Number of bedrooms
BATHS	Number of bathrooms
HEAT_FA	1 if house has forced air heating, 0 otherwise
HEAT_GV	1 if house has gravity-fed heating, 0 otherwise
HEAT_BB	1 if house has electric-baseboard heat, 0 otherwise
AIR	1 if house has air conditioning, 0 otherwise
FIRE	Number of fireplaces
GARAGE	1 if house has a garage, 0 otherwise
ZIP_XX	1 if house is located in ZIP code 972XX, 0 otherwise
DISTANCE_TO_CITY_CENTER	Distance from the centroid of a house's lot to city center (m)
CRIME*	Number of reported crimes within 0.25 miles (402m) during last 12 months
DISTANCE_TO_PARK	Distance to nearest park (km)
PARK_AREA	Area of nearest park (hectares)
NUMBER_OF_STREET_TREES	Number of street trees directly fronting a house's lot
STREET_CA	Crown area of street trees directly fronting a house's lot (m^2)
NUMBER_OF_LOT_TREES	Number of trees on a house's lot
LOT_CROWN_AREA	Crown area of trees on house's lot (m^2)

* Crime data were originally categorical, but we converted them to a continuous variable using the midpoint of categories. Categories were: <1, 1-25, 25-50, 50-100, 100-300, 300-500, >500.

TABLE 2

Regression Results (n=985)

Variable	Coefficient	Standard Error	p value	Marginal Effect
INTERCEPT	5.74	0.092355	0.000	
AGE	0.000544	0.000228	0.017	$0.69
BATHS	0.0605	0.0117	0.000	$79.20
BEDS	0.0869	0.00785	0.000	$115.46
GARAGE	0.0371	0.0115	0.001	$46.83
LOG_SIZE	0.257	0.0216	0.000	$2.80
CRIME	-1.94E-04	8.67E-05	0.026	-$0.25
DISTANCE_TO_PARK	0.0326	0.0154	0.035	$4.15*
DISTANCE_TO_CITY_CENTER	-3.41E-05	3.42E-06	0.000	-$4.33
ZIP_03	0.0389	0.0220	0.078	$50.20
ZIP_06	-0.0581	0.0191	0.002	-$72.20
ZIP_11	0.0418	0.0208	0.045	$54.00
ZIP_12_32	0.0664	0.0271	0.014	$86.98
ZIP_13_18	-0.00822	0.0218	0.706	
ZIP_14_15	0.0548	0.0264	0.038	$71.46
ZIP_16	-0.00210	0.0335	0.950	
ZIP_17_27	0.00035	0.0206	0.987	
ZIP_19	-0.0566	0.0485	0.244	
ZIP_20	0.0285	0.0278	0.304	
ZIP_30	0.110	0.0338	0.001	$147.13
ZIP_33	0.0808	0.0361	0.026	$106.68
ZIP_36	0.0838	0.0344	0.015	$110.71
ZIP_CENT	0.0845	0.0461	0.067	$111.13
NUMBER_OF_LOT_TREES	0.00441	0.00142	0.002	$5.62
NUMBER_OF_STREET_TREES	0.0164	0.00503	0.001	$21.00
R Squared	0.693			

* Per 100 m.

TABLE 3

MEAN VALUE OF SELECTED INDEPENDENT VARIABLES FROM THE STUDY SAMPLE AND FROM THE SAMPLE USED IN DONOVAN AND BUTRY (2010)

Variable	Mean	Mean (previous sales-price hedonic)
SIZE*	126	143
LOT*	614	550
AGE	66	65
BATHS	1.5	1.6
DISTANCE_TO_CITY_CENTER	7,670	7,790
NUMBER_OF_STREET_TREES	0.57	0.56
STREET_CA*	19.80	15.30

* Statistically significant difference ($\alpha = 0.05$) between the two samples based on a two-tailed t-test assuming unequal population variances.

Figures

FIGURE 1

DISTRIBUTION OF SAMPLE IN PORTLAND, OREGON (N=985)

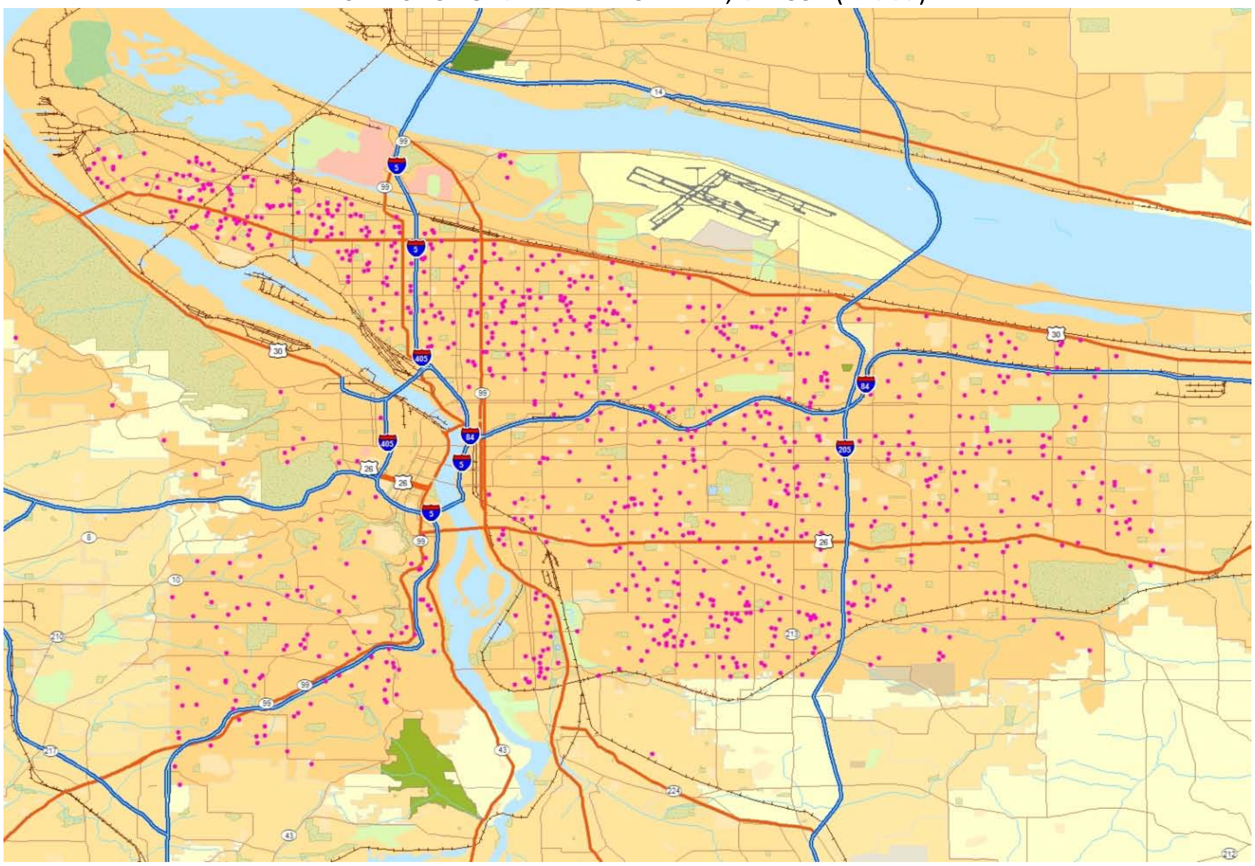

FIGURE 2

SEMIVARIOGRAM OF REGRESSION MODEL RESIDUALS