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Trees in the city: Valuing street trees in Portland, Oregon

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ABSTRACT

We use a hedonic price model to simultaneously estimate the effects of street trees on the sales price and the time-on-market (TOM) of houses in Portland. Oregon. On average. street trees add $8870 to sales price and reduce TOM by 1.7 days. In addition. we found that the benefits of street trees spill over to neighboring houses. Because the provision and maintenance of street trees in Portland is the responsibility of adjacent property owners, our results suggest that if the provision of street trees is left solely to homeowners, then there will be too few street trees from a societal perspective.

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1. Introduction

The discipline of forestry can be traced back to 15th century Europe. and. for much of the intervening period. forestry has concerned itself primarily with the production of wood products. However. during the 20th century, people began to place more value on non-timber forest outputs such as clean water, recreation, and wildlife habitat. These changing values have been reflected in changes in forest management policy and practices. For example. the last 20 years have seen a precipitous decline in the volume of timber harvested from public lands in the U.S. (Warren. 2006). These changing values have made it more difficult to demonstrate the benefits offorest management, as, in contrast to wood products, many non-timber forest outputs do not have an established market price. One sub-discipline of forestry. which deals exclusively in non-timber forest outputs, is urban forestry. The need to demonstrate the benefits of urban forestry is particularly acute, because the costs of urban forestry, on a per-tree basis, are orders of magnitude higher than non-urban forestry (Maco and McPherson. 2003).

Researchers have used a variety of non-market valuation techniques to estimate the value of urban trees. The most frequently used approach has been the hedonic price method. which is often used to estimate the effects of environmental amenities on house prices. Researchers have also used the contingent valuation method. which uses stated-preference data to estimate amenity values. Studies using both methods fall into two main categories: those that estimate the value of proximity to wooded areas. such as parks and open space, and those that estimate the value of individual trees.

Garrod and Willis (1992a) used a hedonic model to estimate the effect of adjacency to Forest Commission land in the United Kingdom. They found that broad leaf trees within a square kilometer (0.4 mile^2) of a house increase sale price. whereas Sitka spruce decrease sales price. In a related study, Garrod and Willis (1992b) found that the amenity value of Forestry Commission land is much lower than timber sales revenues. but that the value of open-access recreation is comparable to timber values, Tyrvainen (2001) used contingent valuation to estimate the value of wooded recreation areas and urban parks in Finland. She found that both have positive amenity values that could be enhanced by forest management. Tyrvainen (1997) used a hedonic model to estimate the effect of proximity to watercourses and wooded recreation areas on apartment sales' prices in joensuu, Finland. She found that both have a significant. positive effect on sales price. In another hedonic study, Tyrvainen and Miettinen (2000) estimated the effect of proximity to forested area on the house price in Salo, Finland. They concluded that a 1-km (0.6-mile) increase in distance from a forested area reduces sales price by 5.9%. In addition. they found that a forest view increases sales price by 4.9%, Luttick (2000) used a hedonic model to examine the effect of a range of environmental amenities on house price in Holland. He found that the largest effect was from a garden facing water (28%), although a range of environmental amenities, such as attractive landscape types, also positively influenced house price. Vesely (2007) used contingent valuation to estimate the value of tree cover in 15 New Zealand cities. She found that respondents are willing to pay 184 NZD (about $149)

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to avoid a 20% reduction in tree cover, Wolf (2004) drew attention to the non-market benefits of urban trees and summarized tools for measuring these benefits. She emphasized the need to consider non-market benefits to ensure adequate provision of urban parks and open spaces. Mansfield et al. (2005) used a hedonic model to estimate the impact of different types of forest cover on the value of land parcels. They conclude that adjacency to private forests adds value to houses, but adjacency to institutional forests does not. Lee et al. (2008) used a hedonic model to evaluate the effect of tree cover and proximity to chemical facilities on house price in Tarrant County, Texas. Consistent with previous studies, they found that tree cover positively influence house price and proximity to a chemical facility decreased house price. However, the authors went one step further and showed that not only does tree cover increase house price directly, but it also partially mitigates the effect of proximity to chemical facilities. Des Rosiers et al. (2002) examined the effect of trees and other landscaping on the sales price of 760 houses in the Quebec Urban Community. They found that an increase in the proportion of tree cover on a lot, relative to the surrounding area, increased sales price, which the authors interpreted as a reflection of the relative scarcity of trees. However, the authors found that if tree cover increased too much, then it had a negative effect on sales price. Finally, they also showed that trees had a bigger impact on sales price in areas with a higher proportion of retired people.

Morales (1980) used the hedonic method to examine the effect of tree cover on house sales in Manchester, Connecticut. He concluded that good tree cover adds 6% to the sales price of a house. However, the study has two major limitations. First, the sample size was low (60). Second, tree cover was represented by a binary variable: good cover or not. In two related studies, Anderson and Cordell (1988a,b) studied the effect of front-yard trees on houses sales in Athens, Georgia. Data on the number of front-yard trees were obtained from Multiple Listing Service photographs. The authors concluded that a front-yard tree added $422 to sales prices. In addition, they noted that front-yard trees increase property tax revenue. In two related studies, McPherson et al. (1999,2005) estimated the costs and benefits of urban trees in six U.S. cities. Benefits included energy savings, carbon dioxide reductions, air quality improvements, reduced storm-water runoff, and aesthetics (The authors used Anderson and Cordell (1988) to estimate the aesthetic benefits of urban trees). In all six cities, the authors concluded that the benefits of urban trees exceed their costs.

House and neighborhood characteristics can also affect a house's time-on-market (TOM) (Taylor, 1999). Several authors have noted a relationship between TOM and selling price (Knight et al., 1994; Anglin et al., 2003), although other studies have demonstrated that this relationship is not necessarily a simple trade-off (Sirmans et al., 1995; Anglin, 2006). However, we could find only one study that has examined the effect of urban trees on TOM. Culp analyzed the effect of a wide variety of variables on the sales price and TOM of 3088 home sales in Lehigh County, Pennsylvania including 14 dummy variables that described urban trees on or close to each property. For example, the variable Large Trees Back took on a value of one if there were trees taller than 35ft (10.7 m) in the rear of the home. Culp found that trees overhanging one side of the house reduced sales price, whereas mature trees on the property increased sales price. Trees on three sides of a house's lot reduced TOM by over half. Large trees to the rear of a house also reduced TOM, but the effect was much smaller.

Although few studies have examined the effect of urban trees on TOM, some have looked at the effect of other environmental amenities on TOM. For example, Huang and Palmquist (2001) investigated the effect of highway noise on house price and TOM; they found it was not correlated with TOM.

Although the problem of valuing urban trees has received considerable attention in the literature, a number of important questions have not been adequately addressed. First, few studies have examined the effect of urban trees on the housing market, and none have explicitly focused on street trees. Those studies that have estimated the value of street trees have relied on Anderson and Cordell (1988), who estimated the value of front-yard trees not street trees. This distinction is important because, as Mansfield et al (2005) point out, "Each type of forest cover provides different amenities to the homeowner and to society at large". Second, individual-tree studies have not examined the effect of tree attributes on the housing market. For example, do trees of different sizes, species, and conditions have differential effects on the housing market? Indeed, most previous studies have not considered individual-tree attributes at all. The only study that has looked at urban trees at the individual-tree level was Anderson and Cordell (1988a,b), and they only considered number of trees. In addition they collected data from photographs not from direct tree measurements. Finally, only one study has examined the effect of urban trees on TOM. A better understanding of how urban trees influence "curb appeal" and reduce TOM may provide a more comprehensive picture of the benefits of urban trees. Failing to account for affects on TOM, if they exist, would result in underestimating urban-tree-based amenity values.

Formally, we hypothesize that street trees influence the sales price and TOM of homes in Portland, Oregon, and that these effects are not limited to adjacent homeowners. In addition, we hypothesize that the magnitude of these effects may be influenced by tree characteristics.

These questions have important public policy implications. For example, in Portland, adjacent property owners are responsible for the costs maintaining street trees. However, if the benefits of the trees spillover to the neighborhood, then it may be appropriate for local government to bear some of the costs of maintaining street trees to produce the socially optimal level of tree cover.

2. Study area and data

Portland is a city in northwest Oregon near the confluence of the Willamette and Columbia Rivers with a population of 537,000 (U.S. Census Bureau 2006 population estimate). Metropolitan Portland, which includes surrounding communities, has a population of approximately 2 million (the 23rd largest metropolitan area in the U.S.). There are approximately 236,000 street trees in Portland, and 26% of the city has canopy cover (Karps, 2007). The Willamette River divides the city into east-side and west-side Portland. We limited our analysis to east-side Portland for two reasons. First, west-side Portland has fewer demarcated pavements and parking strips, which makes it more difficult to determine if a tree is on public or private property. Second, by limiting the geographic scope of the study. we were able to collect more observations.

During summer 2007, we visited 3479 single-family homes, which represented all house sales in east-side Portland between July 1st, 2006, and April 26th, 2007 (Fig. 1). At each house we recorded the number of street trees that fronted the property. This normally meant that the trees were in the parking strip (the strip of grass between the road and the sidewalk): however, on a few occasions, we also included trees planted in a grassy median down the center of the road. We measured diameter and height of each tree. In addition, we recorded the type of the tree (flowering, fruiting, deciduous [non-flowering, non-fruiting], or conifer), whether it was single-stemmed 5 ft (1.5 m) from the ground, whether it showed signs of disease, and whether the crown had been severely pruned (typically to keep the tree away from power lines). We also recorded data about the house: the number of blocks from a busy street (a street designed forthrough travel), presence of pavement damage (whether caused by tree roots or not-in Portland, home-

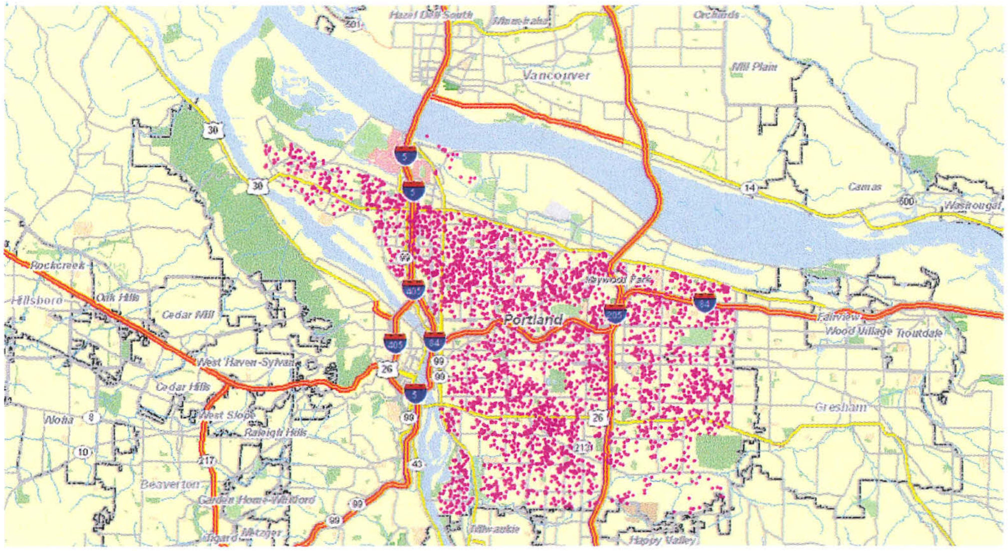

Fig. 1. Study sample of east-side Portland, Oregon, houses sold (in pink) between July 1st, 2006, and April 26th, 2007.

owners are responsible for pavement repairs outside their house), and a subjective judgment of the house's condition (poor, average, or good). Our choice of tree variables was driven by conversations with urban foresters in Portland and elsewhere. All the data collection was conducted by one student, although she was accompanied for one afternoon a week by the lead author for quality-control purposes.

Having collected on-site data, we collected further data remotely. Combining cadastral data with aerial photographs, we calculated the crown area of all the measured trees. In addition, we calculated the crown area of all street trees within 100 ft (30.5 m) of the middle of each house's front property line, but not including those directly fronting the house. This gave us two crown area variables: crown area of trees directly fronting the house and crown area of street trees within 100ft (30.5m) but not including those fronting the house.

The goal of our study is to estimate the value of street trees, but trees on private property could also affect house price. We were not able to gather the same data for trees on private property (due to access limitations). Therefore, we used a geographic information system (GIS) vegetation layer to calculate the percentage tree cover on each lot. The vegetation layer has four classifications: pavement, buildings, grass and shrubs, and trees (Final imagery and image classification produced by the City of Portland Bureau of Environmental Services. Overall classification accuracy 80.5%. KAPPA coefficient 0.610). In addition, we calculated the Euclidean distance of each house from downtown Portland, the distance to the nearest park, and the area of the nearest park using Metro GIS layers. We obtained data about each house (size, age, number of bathrooms, etc.), sales date, and sales price from the Multnomah County Assessor's Office. Finally, we obtained TOM data from the Portland Multiple Listing Service (Houses are sometime re-listed to give the impression that they have just gone on the market. To address this problem, each RMLS listing was checked for multiple listings. Therefore, TOM is in some cases cumulative TOM from multiple listings).

3. Methods

The hedonic price method has been used to estimate the value of a wide range of environmental amenities and disamenities. House price is typically regressed against variables that describe the house (number of bathrooms, for example), variables that describe the neighborhood (school district, for example), and variables that describe the environmental amenity under study: in this case, the number, size, and type of street trees.

3.1. Hedonic price equation

The natural log of the sales price *(p)* was regressed on the naturallog ofTOM in days (r), and house and neighborhood amenities, including the street tree variables, X (The β's denote the model coefficients and e is an error term):

$$\ln(p) = \beta_0 + \beta_T \ln(t) + \mathbf{X}\beta_x + e$$

Variables in X include age of the house in years *(AGE);* number of bathrooms *(BATH);* dummy variables indicating a house in average condition *(COND..AVG)* or good condition *(COND_GOOD);* number of blocks from a busy street *(DIST);* distance to downtown in ft *(DroWN);* a dummy variable indicating a house with a concrete foundation *(FOUNDATION);* the natural log of the finished area in square feet *(AREA);* the natural log of the lot size in square feet (LOD; dummy variables indicating a house with air conditioning *(HEAT_AC),* baseboard heat *(HEAT_BB),* or forced-air heat *(HEAT_FA);* dummy variables indicating a house with a brick fireplace *(FIRE_BRICK),* a hearth fireplace *(F1RE_HEARTH),* or a modular fireplace *(F1RE_MOD);* proportion of tree cover on a lot *(LOY-COVER);* dummy variables indicating the ZIP code of the house (ZIP code 97266 is included in the intercept); dummy variables indicating the month of the sale (january is included in the intercept); number of street trees fronting a house *(NUMBER);* total crown area of street trees directly fronting a house in square feet *(CROWN_HOUSE);* total crown area of street trees within 100 ft (30.5 m) of a house in square feet but not including those directly fronting the house *(CROWN_IOO);* height of the highest street tree fronting a house in feet *(HEIGHT_HIGH);* average height of street trees fronting a house in feet *(HEIGHT_MEAN);* basal area (Basal area is the cross-sectional area of a tree's trunk. We used basal area instead of diameter, because it is more meaningful to sum a measure of area, such as basal area, than a measure of length such as diameter) of the largest street tree fronting a house in square inches *(BABICH);*

Table 1
Summary statistics independent variables.

Variable	Mean	Conditional mean	Minimum	Maximum
AGE	66	75	1	128
DTOWN	26,475	20,730	7122	52,771
AREA	1542	1702	400	4798
LOT	5833	5019	40	40,500
LOT_COVER	0.22	0.23	0	0.99
NUMBER	0.58	1.69	0	4
CROWN_100	906	1773	0	29,497
CROWN_HOUSE	166	485	0	10,476
HEIGHT_HIGH	9	28	0	97
HEIGHT_MEAN	9	26	0	97
BA_HIGH	58	169	0	2,641
BA_TOTAL	80	234	0	4,673
BA_MEAN	50	147	0	2,641
FLOWERING	0.13	0.40	0	1
FRUITING	0.03	0.10	0	1
CONIFEROUS	0.004	0.012	0	1
DECIDUOUS	0.17	0.48	0	1
FORK	0.26	0.77	0	1
SICK	0.02	0.05	0	1
PRUNE	0.01	0.04	0	1

Note 1: The conditional mean was calculated across only those houses with street trees. For example, the average number of street trees fronting a house across the whole sample was 0.58, but considering only houses that had a least one street tree, the average was 1.69.

total basal area of street trees fronting a house in square inches (*BA_TOTAL*); average basal area of street trees fronting a house in square inches (*BA_MEAN*); dummy variables denoting whether a street tree is flowering, fruiting, coniferous, or deciduous (neither flowering nor fruiting); a dummy variable denoting that the majority of street trees fronting a house have forked trunks 5 ft (1.5 m) from the ground (*FORK*); a dummy variable denoting that one of more street trees fronting a house show obvious signs of disease (*SICK*); a dummy variable denoting that one or more street trees fronting a house have severely pruned crowns (*PRUNE*) (typically to keep a tree away from a power line). Table 1 provides summary statistics for all tree variables and selected non-tree variables.

3.2. Time-on-market equation

The natural log of TOM days (*t*) was regressed on the natural log of sale price (*p*) and list date and street tree variables, Z:

$$\ln(t) = \alpha_0 + \alpha_p \ln(p) + \mathbf{Z}\alpha_z + v$$

Variables in Z include dummy variables indicating the month of the listing (January is included in the intercept), a dummy variable denoting 2007, and all the tree variables previously listed in the hedonic price equation section. The α's denote the model coefficients and v is an error term. The TOM (duration) model was specified assuming a lognormal survival function, which is consistent with our assumption that the probability of a sale initially increases over time, then declines.

4. Results

Of the 3479 houses in the original sample, 113 were eliminated because the address was not a single-family home, we could not reliably match aerial photographs and cadastral data, or we simply could not find the house. We visited each of the remaining 3366 houses. Portland Multiple Listing Service did not have TOM records for all of these houses, so those without a record were excluded. In addition, we dropped any house with a list date before January 1st, 2006. This left us with a final sample size of 2608. On average, a house spent 71 days on the market, and had a median price of $259,000.

Because it is well established in the real estate literature that house price and TOM can be codetermined, we estimated expressions for sales price and TOM using two-stage least squares. Codetermination is confirmed based on our Dubin-Wu-Hausman (Davidson and MacKinnon, 1993) tests for endogeneity that reject the nulls that price ($p < 0.01$) and TOM ($p = 0.091$) are exogenous. Several of the tree variables (height and diameter, for example) were collinear, so we did not use a formal stepwise selection procedure. Rather, we iteratively tested different combinations of variables - both linear and non-linear transformations - and eliminated those with p-values greater than 0.1.

4.1. Spatial dependence

Spatial dependence is a statistical issue often found in hedonic models (Taylor, 2003; Donovan et al., 2007). Two types of spatial dependence are common: spatial error and spatial lag dependence. Spatial error dependence occurs when the error term is spatially autoregressive, whereas spatial lag dependence occurs when the dependent variable (either the price or TOM) exhibits autoregressivity (Anselin, 1988). Least-squares estimates are inconsistent if a spatial lag process exists; however, they are only inefficient when a spatial error process is present (Anselin, 1988).

We initially explored the presence of spatial dependence using semivariogram analysis on the residuals of the price and TOM equations (spatially dependent errors can imply either a spatial error or a spatial lag process). A semivariogram graphically displays the results of pairwise comparisons made between the residuals over space. When spatial dependence is present, the difference between residuals is smaller for those observations located closer to one another than those farther apart. Semivariogram analysis allows us to quickly evaluate whether spatial dependence exists without having to specify a spatial weight matrix, which defines how observation are linked across space. If spatial dependence is found, it provides guidance in specifying the spatial weight matrix, which is required for further statistical testing of the spatial process. Two Lagrange multiplier (LM) tests (see Anselin and Hudak., 1992) can be used to determine the type and magnitude of spatial dependence, as the spatial dependence exhibited in the semivariogram analysis could be caused by either a spatial error or lag process.

Our analysis of the semivariograms suggested the presence of spatial dependence in the price equation up to about 2000 ft (609.6 m) (Fig. 2). The evidence of spatial dependence is much weaker for the TOM equation, with any spatial correlation disappearing after about 1000 ft (304.8 m) (Fig. 3). The LM test statistic for spatial error dependence was 26.3 ($p < 0.01$) for the price model indicating spatial dependence. The LM test statistic for spatial error dependence was 2.0 ($p = 0.16$) for the TOM model, thus failing to reject the null of no spatial dependence. In the case of the price model, however, a significant test of spatial error dependence does not eliminate the possibility that a lag process is also present (Anselin et al., 1996). The LM test statistic for spatial lag dependence was 2.1 ($p = 0.15$), indicating the spatial dependence was not due to a spatial lag process. Because the only statistical issue resulting from a spatial error process is inefficiency, and as shown below, the variables of interest were statistically significant, we did not correct for spatial error dependence in our final model estimates.

4.2. Sales price

The effects of household and neighborhood characteristics are consistent with economic theory. In particular, increases in finished area, lot size, and number of bathrooms increased sales price (Table 2). In addition, houses in better condition had higher sales price, as did older houses, houses closer to downtown, houses farther from a busy street, those with air conditioning, and those with

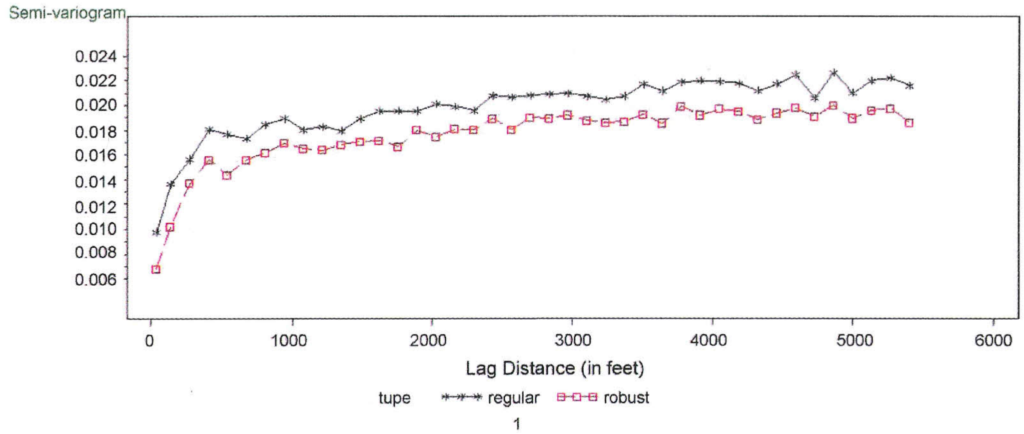

Fig. 2. Semivariogram of the residuals from the sales price equation.

brick or modular fireplaces. Of the 17 dummy variables for ZIP code, 12 were significant (at the 5% level), and all 12 were positive, suggesting that the excluded ZIP code, 97266, is one of the least desirable places to live in East-side Portland. Finally, consistent with previous studies, TOM was negatively correlated with sales price.

Of the tree variables evaluated, only number of trees and crown area within 100 ft (30.5 m) of the house were significant (Table 3). The coefficients on both were positive. Recall that crown area within 100 ft (30.5 m) of a house does not include trees that directly front the house. The majority of tree variables we collected were not significant. This suggests that in future hedonic studies it may be sufficient to only collect data on crown area and number of trees.

On average, a house had 0.558 street trees in front of it and 904 ft^2 (84 m^2) of canopy cover within 100 ft (30.5 m). When combined, the two tree variables (evaluated at their means) added $8870 to the price of a house, which represents 3.0% of median sales price. For comparison, this is equivalent to adding 129 finished ft^2 (12 m^2) to a house. There are 126,176 single-family residences in east-side Portland, and 152,636 in Portland as a whole. Applying the average effect of trees to all east-side houses yields a total value of $1.12 billion. Extrapolating to west-side Portland is more problematic, as we do not know if the west-side housing market or the stock of street trees is fundamentally different. Given these caveats, applying the average tree effect to all houses in Portland yields a total value of $1.35 billion. If this increase is also reflected in an increase in a house's assessed value, then trees may increase property tax revenues. In 2007, the property tax rate in Portland was $21.80 per $1000 of assessed value. This was based on a mean assessed value of $154,500, which is 52% of the mean sales price in our sample. Assuming that street trees increase assessed value by 52% as much as they increase sales price, street trees increase property tax revenues in east-side Portland by $12.6 million annually and by $15.3 million annually in Portland as a whole. The annual benefits of street trees can be estimated by multiplying their total value by a specified discount rate (Rideout and Hesseln, 1997). If we assume a discount rate of 4%, then the impact of street trees on the housing market translates into annual benefits of $45 million for east-side Portland and $54 million for the whole city. The city of Portland estimated the annual maintenance cost (Maintenance costs include planting and tree removal costs as well as traditional maintenance costs such as pruning and leaf removal.) for Portland's street trees to be $4.61 million, of which $3.33 million is borne by private landowners and the remaining $1.28 million by the city of Portland (Karps, 2007). Therefore, the benefit cost ratio of Portland's street trees is almost 12-1.

To this point, we have considered the effect of one or more trees on the price of a single house, which is typical for a hedonic analysis. However, it is also useful to evaluate the effect of a single tree on multiple houses. Let us consider a tree with a canopy cover of 312 ft^2

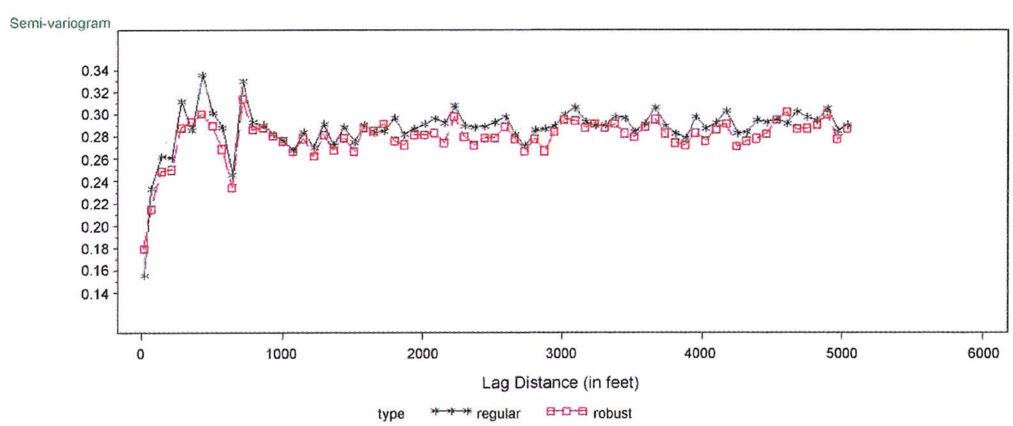

Fig. 3. Semivariogram of the residuals from the time-on-market equation.

Table 2
Regression results for house price model (n = 2608, R-squared = 0.83).

Variable	Coefficient	SE	p-Stat	Marginal effect*
INTERCEPT	8.52	0.102	0.000	
TOM	−1.31E−02	5.66E−03	0.021	−$58
AGE	0.00105	1.52E−04	0.000	$290
BATH	0.0563	0.00641	0.000	$15,987
COND_AVG	0.0914	0.013	0.000	$24,743
COND_GOOD	0.219	0.0146	0.000	$64,377
DIST	0.0157	0.00292	0.000	$4,368
DTOWN	−6.45E−06	9.40E−07	0.000	−$1.78
FOUNDATION	0.0551	0.0245	0.024	$14,810
LN(AREA)	0.36	0.0119	0.000	$70
LN(LOT)	0.125	0.0086	0.000	$6.36
HEAT_AC	0.0564	0.0142	0.000	$15,887
HEAT_BB	−0.0402	0.0155	0.01	−$10,917
HEAT_FA	0.00528	0.0122	0.667	$1,456
FIRE_BRICK	0.0686	0.00735	0.000	$18,900
FIRE_HEARTH	0.0103	0.0151	0.497	$2,856
FIRE_MOD	0.0588	0.013	0.000	$16,630
ZIP_202	0.248	0.0225	0.000	$76,037
ZIP_203	0.0296	0.0223	0.185	$8,284
ZIP_206	0.0778	0.18	0.000	$22,116
ZIP_211	0.156	0.0233	0.000	$45,912
ZIP_212	0.324	0.0279	0.000	$103,478
ZIP_213	0.194	0.0209	0.000	$58,245
ZIP_214	0.297	0.0282	0.000	$94,262
ZIP_215	0.236	0.0249	0.000	$72,920
ZIP_216	0.0335	0.0199	0.093	$9,391
ZIP_217	0.0797	0.0244	0.001	$22,761
ZIP_218	1.77E−03	0.0242	0.942	$489
ZIP_220	0.00214	0.0173	0.901	$591
ZIP_227	0.0615	0.0446	0.168	$17,502
ZIP_230	0.0857	0.0196	0.000	$25,547
ZIP_232	0.32	0.037	0.000	$103,737
ZIP_233	0.083	0.0199	0.000	$23,790
ZIP_236	0.0716	0.0214	0.001	$20,429
SALE_JUL	−1.18E−02	0.136	0.389	−$3,244
SALE_AUG	−0.0129	0.0134	0.337	−$3,545
SALE_SEP	−0.0258	0.0142	0.07	−$7,051
SALE_OCT	−0.0167	0.0136	0.221	$4,581
SALE_NOV	1.28E−03	0.014	0.927	$353
SALE_DEC	−0.0189	0.0143	0.186	−$5,177
SALE_FEB	−0.00969	0.0161	0.546	−$2,662
SALE_MAR	−0.0157	0.158	0.321	−$4,303
SALE_APR	0.0571	0.0297	0.055	$16,209
NUMBER	0.0255	0.00367	0.000	$7,130
CROWN_100	1.96E−05	1.85E−06	0.000	$5.41

*Marginal values evaluated at mean of independent variables.

Table 3
TOM regression results (n = 2608, R-squared = 0.20).

Variable	Coefficient	SE	p-Stat	Marginal effect (days)*
INTERCEPT	4.49	0.517	0.000	
LN(PRICE)	7.97E−02	4.07E−02	0.05	0.014**
LIST_FEB	−0.207	0.0822	0.012	−10.5
LIST_MAR	−0.396	0.109	0.000	−18.4
LIST_APR	−0.675	0.116	0.000	−28.1
LIST_MAY	−1.12	0.106	0.000	−41.1
LIST_JUN	−1.49	0.103	0.000	−55.1
LIST_JUL	−1.55	0.103	0.000	−54.8
LIST_AUG	−1.44	0.104	0.000	−52.1
LIST_SEP	−1.47	0.105	0.000	−51.0
LIST_OCT	−1.46	0.104	0.000	−49.9
LIST_NOV	−1.46	0.107	0.000	−47.3
LIST_DEC	−1.49	0.116	0.000	−45.4
LIST_2007	−1.77	0.0939	0.000	−53.9
NUMBER	−0.0348	0.0135	0.01	−2.1
CROWN_100	−1.06E−05	6.73E−06	0.116	−0.076***

*Marginal values evaluated at mean of independent variables.
** Marginal effect is for an increment of $1000.
*** Marginal effect is for an increment of 100 square feet.

(29m²) (the average for our sample). This tree adds $7130 to the price of the house it fronts. However, it also positively influences the price of houses within 100ft (30.5 m). We drew a random sample of 100 houses from our larger sample of 2608, and found that, on average, there are 7.6 houses within 100ft (30.5 m) of a street tree. Therefore, a tree with 312 ft² (29 m²) of canopy cover adds, on average, $12,828 to the value of neighboring houses, and the total benefit of a tree with 312 ft² (29m²) of canopy cover is $19,958.

The spillover benefits of a street tree are not experienced by the homeowner whose property the tree fronts. Therefore, if the provision and maintenance of street trees is left to individual homeowners, as it is now, they will likely under-invest in street trees from a societal perspective. A number of policy remedies are possible. The city of Portland could pay for the planting of street trees-currently, they do not. Alternatively, the city could provide homeowners with a property-tax break depending on the number and size of street trees they are responsible for. The spillover-to-direct -benefit ratio could be used as a rough guide for the efficient mix of public to private funding for street trees.

4.3. Time-an-market

We used a more parsimonious model for TOM than price, because we believed that price captures the effects of many of the house and neighborhood variables (If neighborhood and house variables are included with price, they are mostly insignificant.). In addition, we used list date as opposed to sale date in the TOM equation. Because list dates span more than 1 year, we also added a dummy variable for houses listed in 2007. As theory suggests, and consistent with the price equation, an increase in sales price increased TOM. In addition, houses listed in any month other than January sold quicker, as did houses listed in 2007. Finally, both number of trees and crown area within 100 ft (30.5 m) of a house reduce TOM. Evaluated at their means, the two tree variables reduce TOM by an average of 1.7 days. Table 3 shows that a decrease in TOM increases sales price. A reduction of 1.7 days in TOM increases sales price by $88. Although the effect of trees on TOM is statistically significant, it is economically irrelevant. Our results are in contrast to Culp (2008), who showed that trees can reduce TOM by over 50%. There are a number of possible explanations for this apparent discrepancy. Culp used dummy variables to describe tree cover, whereas we used continuous variables. The variables that had the biggest influence in Culp's model described trees on a house's lot not street trees. Finally, there may be systematic differences between the two housing markets studied.

5. Discussion

We used a hedonic model to estimate the value of street trees in Portland. We found that the number of street trees fronting the property and crown area within 100 ft (30.5 m) of a house positively influence sales price. Combined they, on average, added $8870 to the sales price of a house.

Results from this study have several major policy implications. In Portland, the benefits of street trees significantly outweigh their maintenance costs. However, only about a third of the houses in our sample were fronted by street trees. Given our study results, and the number of houses without street trees, the benefits of increased urban forestry investment are likely to justify the costs. However, care should be taken when determining the appropriate mechanism for increasing funding. Simply planting street trees without consulting homeowners would be a mistake, as homeowners place different values on different types of trees. Indeed, some homeowners do not like trees of any type: they block views, drop leaves, and can damage pavements. For these reasons, a subsidy or property-tax break might be an appropriate way to increase the number of street trees. Homeowners would be free to choose the number and type of trees they prefer (given the constraints of the site).

Our results show that street-tree benefits for neighboring houses increase as a tree's crown area increases. However, the benefits to the house the tree fronts do not increase with crown area. This may seem contradictory. However, it may be because crown area in front of a house is collinear with crown area within 100 ft (30.5 m). Similarly, if the ZIP code variables are excluded, then the height of the highest tree outside a house becomes very significant, but tall trees are found disproportionately in some expensive neighborhoods. Therefore, without the ZIP code variables, the height of the highest tree is acting as a proxy for neighborhood. Nonetheless, the height of the highest tree may affect sales price, but the signal may be lost because of collinearity with some ZIP code variables.

The insignificance of crown area on a house's lot (LOT_COVER) was surprising. If street trees increase sales price, why do not trees on the lot? We offer four possible explanations for this result. First, there is little difference in private tree cover between houses with street trees and those without. Table 1 indicates that proportion of private tree cover on a lot for the entire sample was 0.22, whereas, the proportion of private tree cover for homes with street trees was 0.23. Second, the GIS vegetation layer we used to estimate LOT_COVER was only 80% accurate. Third, LOT_COVER only included crown area that fell within a house's property boundary. However, the crown of many trees overhangs neighboring properties. Fourth, LOT_COVER may be collinear with other variables included in the model. although it did not appear to be collinear with the street -tree variables (dropping the street tree variables from the model did not affect the significance of LOT_COVER). To address these problems, future studies may wish to make use of advances in remote sensing. In particular, LIDAR could provide crown area and tree height data on private land, although the problem of tree crowns overlapping neighboring properties may require some innovative programming to overcome.

Extrapolating study results to other cities may be problematic. Ideally, similar hedonic studies would be carried out in cities of different size, climate, demographic makeup, etc. Absent such studies, it would probably be safer to extrapolate results to cities with similar housing markets, demographics, and stocks of street trees. However, the relative size of the costs and benefits of street trees in Portland, and the consistency of our results with other studies, suggest that urban forestry investments are likely to yield substantial benefits. In addition, street trees in other cities are likely to have positive spillover effects, although the extent and size of the spillover may differ.

A recommendation to increase investment in urban forestry raises the question of who should bear the costs. In Portland, and many other cities, the provision and maintenance of street trees is solely the responsibility of the adjacent homeowner. Our results suggest that to prevent under-investment in street trees, which provide benefits to neighborhoods, the city may find it necessary to bear a larger proportion of the costs.

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