The Impact of Mature Trees on House Values and on Residential Location Choices in Quebec City

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Abstract: When choosing their home, households are willing to maximize their satisfaction and utility while trying to avoid noise and inconvenience. Along with economic constraints, this decision process involves several types of criteria, including preferences and perception of environment in the neighbourhood. Previous research in spatial economy has addressed the impact of vegetation and environment quality on single-family house values, using hedonic price models. However, assessing the economic valuation of trees is not sufficient to fully understand the choice-setting mechanisms behind the conversion of environmental preferences into residential location choices. New modelling approaches integrating behaviour, attitudes, tradeoffs and motivations could certainly improve our understanding of people's valuation of nature. This paper develops such a behavioural model considering a housing market which was firstly analysed using the hedonic modelling approach. Logistic regression was then used in order to model households' propensity for buying a house on a wooded lot (with mature trees). Our purpose is to highlight the potential of combining economic and behavioural modelling to enhance understanding of landscaping in urban regions. Our research integrates various data sets collected in Quebec City from 1993 to 2001: an opinion poll of 640-home buyers; a summary of their transactions (sale price); in-site surveys of properties to assess vegetation status; socio-economic attributes of families; census data; accessibility to services modelled using GIS; finally, a full description of transacted homes. Results indicate that impact of mature trees on house value is highly related to family composition and stated appreciation of wooded areas. Effect varies according to the socio-economic status of the neighbourhood, ranging from -9% to 15%. Furthermore, choosing a location with mature trees imply compromising on both access to regional and local-level services and the depreciation status of the house. Moreover, this choice is closely related to household composition and stated preferences for wooded locations.

Keywords: Wooded areas; House value; Residential location choices; Value of mature trees; Modelling

1. INTRODUCTION

Making a choice of home is a complex and long-term decision taken by households trying to maximize their satisfaction and utility level. They are also willing to avoid inconvenience and noise, often making compromises on location. Along with economic constraints, this decision process involves several types of criteria, including values, attitudes, household composition, as well as perception of environment and neighbourhood. Previous research in spatial economy has assessed the impact of vegetation and environment quality on house values, using hedonic price modelling. Hedonic price modelling uses multiple regression techniques to assess the marginal contribution of property attributes to the sale price, hence assessing the market value of a property. However, measuring the economic valuation of landscaping is not sufficient to fully understand the choice-setting mechanisms behind the effect of trees on residential location choices. New modelling approaches integrating behavioural concepts of attitudes, tradeoffs (accessibility versus nature) and motivations could certainly improve our understanding of people's valuation of nature.

This paper develops such a behavioural model considering a housing market which was firstly analysed using an hedonic approach to assess economic valuation of property specifics, location and environment. Logistic regression was then used in order to model households' propensity for buying a house on a wooded lot (with mature trees measuring at least 10 metres) and in wooded neighbourhoods. Our purpose is to highlight the potential of combining economic and behavioural modelling in a two-step approach in order to further our understanding of landscaping valuation in urban regions.

This research is based on a detailed field survey of 640 single-family homes transacted between 1993 and 2000 on the territory of Quebec City. It integrates various data sets: an opinion poll of recent home buyers; a summary of their transactions (sale price); in-site visits of properties to assess vegetation status; socio-economic attributes of families; and full description of their homes (property specifics). These data are located using a geographical information system (GIS).

2. LITERATURE REVIEW

Several authors have investigated the effect of trees and landscaping on house values. Payne (1973), using standard valuation techniques, concludes that the market value of a single-family house receives a 7% premium on average (between 5% and 15%) due to trees, provided that there are less than thirty trees on the lot. Payne and Strom (1975) estimate the value of seven combinations of tree cover for a twelve-acre parcel of unimproved residential land in Amherst (Massachusetts). Arrangements with trees are valuated 30% higher than others, land price being maximized with a 67% wooded cover.

Perception studies were also performed over the past decades. Using transacted suburban properties in Champaign-Urbana (Illinois), Orland *et al.* (1992) conducted a study based on photographs taken from the street. Three different size-class trees are then superimposed using video-simulation. While public groups' evaluations show that house attractiveness is highly correlated with actual sale prices, tree size had little effect on evaluations. While tree presence or size exerts no impact on less expensive homes, a slight increase in value was noted for more expensive houses when smaller trees were added, but price decreased with larger trees. Kuo *et al.* (1998) assess the preference pattern of 100 residents of high-rise buildings surrounding a public open space in a densely populated neighbourhood of Chicago (Illinois). Both tree planting density and grass maintenance are tested. While the presence of trees has strong, positive effects on residents' ratings for the courtyard, grass maintenance has a positive impact on sense of safety, particularly when there are fewer trees. Combining factor analysis and multiple regression techniques, Morales *et al.* (1976) studied 60 home sales in Manchester (Connecticut). With 83% of price variations explained by the model, authors conclude that a good tree cover could raise total value by as much as 6% to 9%. According to Seila and Anderson (1982), newly built houses command prices that are 7% higher when located on tree-planted lots rather than on bare ones. Anderson and Cordell (1985) performed a first analysis on some 800 single-family houses sold over the 1978-1980 period in Athens (Georgia). The average house sold for about $47 000 and had five front-yard trees visible. The study led to the conclusion that the presence of trees adds a 3% to 5% premium to sale price, although other lot and building features associated with tree cover could explain part of this increment in value. In a second study by Anderson and Cordell (1988) on a similar size sample involving cheaper properties (mean sale price at $38 100), the rise in market value associated with the presence of intermediate and large size trees stands within the 3.5% to 4.5% range.

Analysing variations of house prices in the Netherlands, Luttik (2000) isolates the positive effect of water bodies and open spaces, but the hypothesis that a green structure commands a premium had to be rejected in six cases out of eight. In the two cases where this variable emerges as significant, the increment in value associated with the presence of trees or the proximity to green areas is about 7%. Dombrow *et al.* (2000) conducted a study on a sample of 269 single-family house sales, with mean price standing at $93 272. Using a semi-log functional form, a dummy variable is included in the equation to account for the presence of mature trees. The market-derived estimate suggests that mature trees contribute 2% of home values. Finally, a study performed in Quebec City by Des Rosiers *et al.* (2002) using interactions between landscaping and census data suggests that valuation of vegetation is linked to life cycles and is partly related to comparison of the targeted property with its neighbours. Dense tree cover can decrease value by about 2% while landscaped patio, a hedge as well as landscaped curbs add respectively 12.4%, 3.6% and 4.4% to the market value of a house.

To the best of our knowledge, previous studies did not integrate the attributes of home buyers in the analysis. Moreover, they did not explicitly test for the effect of their stated preference about presence of trees on house valuation and residential location choice. That is the specific purpose of this paper.

3. ANALYTICAL APPROACH

The hedonic approach is used to measure the impact of tree cover on home prices. In previous studies, little attention has been devoted to relationships between landscaping and people's wishes. It can be assumed that family with children and people who appreciate the benefits of nature should be more open to location compromise (lowering accessibility to urban amenities) and should be more prone to devote part of their housing budget on landscaping. In an attempt to circumscribe the phenomenon, we measure the increment in value associated with the presence of mature trees while simultaneously controlling for potential inconveniences related to a greater distance to services and buyer's family structure.

Furthermore, logistic regression techniques are used in order to model households' propensity for buying a house on a wooded lot (with mature trees measuring at least 10 metres). Logistic regression is used to test the marginal effect of household attributes and stated preferences on the probability to move towards a wooded location. Finally, a two-step approach combining hedonic and binary logistic models is developed to illustrate their complementary role.

Each property is described using a large set (nearly 80) of specific attributes and neighbourhood-related attributes computed using GIS functions (Table 1). Travel times and census data are related with the home through linkage to the nearest street corner (accessibility) or to point-in-polygon (census data). In order to avoid multicollinearity, census data (demographics, education, income, household structures, ...) and accessibility to services (distance and travel time to schools, shopping centres...) are summarized using principal component analysis to identify uncorrelated dimensions of the urban structure. Other externalities are measured using buffers or distance statistics from features that are known to produce externalities (e.g. motorways exits). Table 1 shows the attributes found to have a significant relationship with the sale price or with the propensity of buyers to choose a property with mature trees. It is a mix of 1) **property specifics** (living area, lot size, apparent age of the building taking into account depreciation or renovations, …); 2) **accessibility to services** and principal components of the **socio-economic milieu** using census data for 1991, Euclidean distances of each house to some specific amenities (high school, freeways, …) and GIS-modelled travel times using a topological road network within TransCAD; and 3) field-observed **vegetation status** and opinion poll-collected **buyer-related attributes**, including spontaneous self-declaration of trees on the premises when identifying positive features of their new home (13.7% of respondents).

Although the two first sets of variables are typical of most hedonic price study, the last one has not been used previously. In 2000 and 2001, we conducted two data collection initiatives aimed at improving our understanding of landscaping valuation by recent home buyers. Drawing a random sample out of our 30 000 single-family house transactions database, we conducted a telephone poll among home owners in order to collect information about themselves, their household, their preferences and their appreciation (positive and negative features) of their new home and neighbourhood. At the same time a field survey was conducted using a systematic approach to collect data about landscaping, quality of view, improvement and other outdoor details pertaining to each location. Finally, a front view photograph was took for more than 800 single-family houses. The 640 cases used for this study are those for which we have all information, including the annual income of the buyer’s household and the education level of the opinion poll respondent (one of the adults belonging to the household).

We devised a two-stage procedure using a semi-log hedonic model (multiplicative form) to assess specific contributions to house value and binary logistic regression to model the likeliness of choosing a property with mature trees. Final models are shown in Tables 2 and 3, respectively. Models where integrated within a spreadsheet to make simulations computing simultaneously variations of house price and probability to retain a wooded property under specific constraints related to the property, to its value, to its location, to the urban structure, and more importantly, to the buyers own preferences and goals. Such a simulator was used to compute sensitivity of home value (paid price) and propensity to select a wooded location while keeping other factors constant (ceteris paribus). Preliminary results are shown in next section.

Although quite useful for explanatory purposes, integrating large sets of variables into linear regression models may prove problematic. Multicollinearity, autocorrelation (temporal or spatial) and heteroskedasticity problems should first find solutions in order to test hypotheses. For example, sorting out accessibility and socio-economic attributes can prove quite tricky considering the cross-influences between these two sets of factors. In this study, the procedure followed involves a succession of checks designed to achieve best model performances, subject to coefficient stability in the regression model, by specifically handling interactive variation of price effects over time and space, thereby removing autocorrelation problems.

When trying to model relationships taking place in space, one should consider the structural effect of proximity on likeness of observations. Moran’s I was used to test the existence of significant spatial autocorrelation among close observations. While it is normal to observe autocorrelation between pairs of neighbours in field-measured data, its persistence in regression model’s residuals is highly detrimental to coefficient stability and to the robustness of hypothesis testing. This means that some spatial variation is not accounted for by the model, yielding local instability on the appropriateness of predicted values. Tables 2 and 3 indicates that both of our models are based on spatially correlated dependent variables (sale price: I=.467 – p=.003; and presence of mature trees:

I=.445 – p=.005). However, both models' residuals do not show significant spatial autocorrelation (hedonic model residuals: I=.119 – p=.242; logistic model residuals: I=.013 – p=.465), thereby indicating that model specification is appropriate. In the hedonic model, multicollinearity is well under control with all but one VIFs (variance inflation factors) being smaller than 5. Finally, heteroskedasticity in the hedonic model is kept to a minimum using the semi-log form.

4. RESULTS AND DISCUSSION

The hedonic model (Table 2) takes into account more than 84% (adj. R-Square .846) of the variation of price on the market, yielding standard error of estimate of .134 which should be compared to an original standard deviation of .341. All regression coefficients are significant to the 5% rejection level. Residuals are not autocorrelated in space (p=.242). The binary logistic regression (Table 3) involves mostly interactions between variables (the "*" sign) and is highly significant (Chi-square p=.000). Confusion matrix indicates that it correctly classifies more than 76% of observed cases. All regression coefficients are significant to the 5% rejection level. The models define exponential functions that were integrated to build a simulator computing sensitivity of house value or propensity to choose a wooded location when changing some parameters while holding other factors constant (ceteris paribus).

Table 4. Effect of mature trees on paid price for house considering household of buyer, perception of benefits and socio-economic status of the neighbourhood

Status of neighbd.	Household without child		Family with children	
	Benefits not appreciated	Benefits appreciated	Benefits not appreciated	Benefits appreciated
High	0%	4%	10%	15%
Above	0%	4%	4%	8%
Middle	0%	4%	-3%	1%
Low	0%	4%	-9%	-5%

Table 4 presents the marginal effect of mature trees on home value (%), considering interactions with socio-economic status of the neighbourhood, family structure (without/with children) and self-declared appreciation of benefits from trees on the premises. Appreciation of benefits gives an overall premium of about 4%. Obviously, family with children do not behave like childless households and adjust their appreciation to the socio-economic status of their living neighbourhood (effects ranging from -9% to 15%). In line with previous findings, trees can have an adverse effect on house value in poorer neighbourhoods and could increase value by about 15% in high socio-economic status neighbourhoods.

Obviously, mature trees take time to grow. If someone wants mature trees with a newly built house, this will imply a larger lot size allowing for conservation of previous vegetation. However, cost of land increases with proximity to services (location rent), yielding a cost constraint for combining nature and accessibility to services. Table 5 displays the likelihood of buying a wooded property, considering interactions among buyers stated appreciation of trees, apparent age of the property (allowing for depreciation and renovation), travel time to CBD and to regional-level shopping facilities. Probabilities varies from 4% (very unlikely situation) to 84%. Self appreciation of vegetation has a strong effect on the decision: for a house aged 25, it doubles the propensity near the city centre (27%/14%) while the odds ratio is slightly decreasing as commuting inconvenience grows (tree lovers are less enthusiastic – 84%/69%).

Table 5. Probability of choosing a property with mature trees (with average equipment and socio-economic status neighbourhood) according to travel time (TT) and apparent age of house (years)

Appar. age (years)	Buyer don't appreciate impact of trees			Buyer appreciate impact of trees		
	TT to CBD (minutes)			TT to CBD (minutes)		
	8	15	25	8	15	25
	TT to Regional ShCtr			TT to Regional ShCtr		
	5	8	12	5	8	12
10	4%	9%	23%	10%	19%	40%
15	6%	14%	36%	14%	28%	58%
25	14%	32%	69%	27%	53%	84%

In line with their economic valuation of vegetation, childless households and families show remarkable differences in their propensity to choose a wooded property (odds ratios are always less that .5 in childless households). However, interactions with distance to the closest high school (proxy of local services) and self appreciation of trees show very similar trends: remote locations act as a disincentive.

Table 6. Probability of choosing a property with mature trees (cottage with average equipment and location) according to household composition and distance to the nearest high school (metres)

Dist. to school	Household without child – No pool		Family with children * Excavated pool	
	Don't appreciate	Appreciate	Don't appreciate	Appreciate
500	15%	31%	44%	66%
1000	13%	26%	38%	59%
2000	8%	17%	26%	45%
3000	5%	11%	17%	31%

5. CONCLUSION

This worked example shows the benefits of considering interactions between home buyers preferences, urban structure and economic features for assessing the value of trees in an urban landscape. Our purpose was not to strengthen hedonic modelling itself, but to enhance our understanding on the complex linkages between housing prices and the appreciation of nature in North American cities. However, similar models must be designed for several locations before findings can be generalized. Also, interactions between access to local services and a preference for wooded neighbourhoods may not be monotonic, an issue which deserves further investigation. It is finally necessary to integrate temporal trends in the housing demand itself, and in the transformation of spatial interactions linked as they are to population aging and its long-term replacement with, eventually, change in valuation of natural environment.

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Table 1. Operational definition of variables

Dependent variables (N=640)	Minimum	Maximum	Mean	Std. Dev.
Sale price ($)	54,000	460,000	114,081	48,553
Natural logarithm of sale price ($)	10.89674	13.03898	11.57938	0.34089
Property with mature trees (>10 metres)	0	1	0.412	0.492
Property specifics	Minimum	Maximum	Mean	Std. Dev.
Bungalow (one story detached house)	0	1	0.462	0.498
Cottage (more than one story detached house)	0	1	0.356	0.479
Living area (square metres)	46.45	376.16	121.47	39.63
Natural logarithm of living area (square metres)	3.83838	5.93001	4.75425	0.29438
(Natural logarithm of living area – 4.75425) * Cottage	-0.22017	1.17724	0.09548	0.18929
Lot size (square metres)	107.77	5438.80	625.97	368.87
Natural logarithm of lot size (square metres)	4.68000	8.60131	6.34453	0.41038
(Natural logarithm of lot size – 6.34453) * Cottage	-1.01667	2.25579	0.03818	0.23247
Ratio of sale price ($) / lot size (square metres)	27.36	1,037.92	207.24	102.46
Apparent age (years – depreciation and renovation)	-1	51	16.22	11.97
Excavated pool	0	1	0.062	0.242
Superior floor quality (made of hard wood)	0	1	0.482	0.500
Basement is finished	0	1	0.558	0.496
Attached garage	0	1	0.075	0.263
Detached garage along a cottage	0	1	0.073	0.261
Number of fireplaces	0	3	0.301	0.486
Local tax rate ($ /$100 of assessed value)	1.199	2.725	2.101	0.393
Accessibility to services and socio-economic milieu	Minimum	Maximum	Mean	Std. Dev.
Travel time to Quebec City centre by car (minutes)	1.28	23.23	13.83	3.69
Natural logarithm of distance to nearest freeway exit (metres)	4.17439	8.53050	6.99083	0.70658
High accessibility to regional-level services (factor analysis)	-2.03074	1.65950	0.04484	0.87981
Socio-economic status of the neighbourhood (factor analysis)	-1.64554	2.77619	0.61040	0.96192
(Regional accessibility – 0.04484) * (Socio-economic – 0.61040)	-1.44501	3.62362	0.53530	0.77254
High accessibility to local-level services (factor analysis)	-3.45543	1.21605	-0.18099	0.80123
Cottage in new suburbs inhabited by high proportion of families	-2.43441	2.28625	0.11197	0.72885
Euclidean distance to the nearest high school (metres)	89	7,149	1,608	1,126
Travel time to the nearest regional-level shopping centre (minutes)	0.94	18.26	8.75	3.64
Vegetation and buyer-related attributes	Minimum	Maximum	Mean	Std. Dev.
Mature trees * (Socio-economic – 0.61040) * Family with children	-2.25157	2.17016	0.06852	0.60880
Adjacent properties wooded > 80% * Buyer holds college degree	0	1	0.019	0.136
Vegetation on lot was an incentive to buy this home (opinion poll)	0	1	0.137	0.344
Wooded area of adjacent properties (%)	0	100	42.902	20.631
Wooded area of adjacent properties * Buyer < 30 years old (%)	0	70	2.512	10.387
Wooded area of adjacent properties * Buyer's household income < $40K (%)	0	80	3.136	12.067
Wooded area of adjacent properties * Buyer's household income > $80K (%)	0	100	11.264	22.634
Ratio of property assessed value ($) / Buyer's household income ($)	0.675	9.750	1.861	0.892
Buyer has a family with children (one child or more)	0	1	0.747	0.434

Table 2. Hedonic model of sale price (multiplicative form)

Dependent variable and model summary	Minimum	Maximum	Mean	Std. Dev.
Natural logarithm of sale price ($) -- (N= 640)	10.89674	13.03898	11.57938	0.34089
Adjusted R square = .846 Std. Error of the Estimate = 0.1338 ANOVA – F = 153.929 p = .000				
Spatial autocorrelation Moran's I Dependent = .46764; p = .003 Moran's I Residuals = .11926; p = .242				

Property specifics	B	Beta	t	Sig.	VIF
(Constant)	9.073419		44.096	.000	
Natural logarithm of living area (square metres)	.333124	.288	9.786	.000	3.593
(Natural logarithm of living area – 4.75425) * Cottage	.354665	.197	6.842	.000	3.444
Natural logarithm of lot size (square metres)	.162718	.196	9.286	.000	1.850
(Natural logarithm of lot size – 6.34453) * Cottage	-.096297	-.066	-3.158	.002	1.797
Apparent age (years – depreciation and renovation)	-.009157	-.322	-14.463	.000	2.057
Excavated pool	.135987	.097	5.776	.000	1.162
Superior floor quality (made of hard wood)	.065869	.097	5.675	.000	1.205
Basement is finished	.057207	.083	4.936	.000	1.187
Attached garage	.098269	.076	4.436	.000	1.218
Detached garage * Cottage	.070305	.054	3.098	.002	1.254
Local tax rate ($ /$100 of assessed value)	-.109805	-.127	-5.020	.000	2.643
Accessibility to services and socio-economic milieu					
Travel time to Quebec City centre by car (minutes)	-.009496	-.103	-3.606	.000	3.377
Natural logarithm of distance to nearest freeway exit (metres)	.035703	.074	3.456	.001	1.905
High accessibility to regional-level services (factor analysis)	.111619	.288	8.162	.000	5.179
(Regional accessibility – 0.04484) * (Socio-economic – 0.61040)	.035475	.080	4.567	.000	1.288
High accessibility to local-level services (factor analysis)	.045117	.106	4.370	.000	2.448
Cottage in new suburbs inhabited by high proportion of families	.022803	.049	2.586	.010	1.478
Vegetation and buyer-related attributes					
Mature trees * (socio-economic status – 0.61040) * Family with children	.052111	.093	4.762	.000	1.588
Adjacent properties wooded > 80% * Buyer holds college degree	.111725	.044	2.621	.009	1.196
Vegetation on lot was an incentive to buy this home (opinion poll)	.042674	.043	2.670	.008	1.084
Wooded area of adjacent properties * Buyer < 30 years old (%)	-.001229	-.037	-2.356	.019	1.050
Wooded area of adjacent properties * Buyer's household income < $40K (%)	-.001498	-.053	-3.270	.001	1.093
Wooded area of adjacent properties * Buyer's household income > $80K (%)	.001253	.083	4.435	.000	1.464

Table 3. Binary logistic model for estimating probability of buying a property with mature trees

Dependent variable and model summary	Minimum	Maximum	Mean	Std. Dev.
Property with mature trees (>10 metres) – (N=640)	0	1	0.412	0.492
Model Chi-square = 260.895; p = .000 -2 Log likelihood = 608.755 Nagelkerke R Square = .450				
76.2 % of cases are correctly classified by the model Cox & Snell R Square = .334				
Spatial autocorrelation Moran's I Dependent = .44596; p = .005 Moran's I Residuals = .01337; p = .465				

Property specifics	B	Wald	Sig.	Exp(B)
(Constant)	-5.284780	49.569	.000	.005068
Apparent age of the property (years) * Buyer's household income ($K)	.000858	15.764	.000	1.000858
Excavated pool * Family with children * Apparent age	.088261	4.776	.029	1.092273
Number of fireplaces * Wooded area of adjacent properties (%) * Household income ($K)	.000169	6.828	.009	1.000169
Accessibility to services and socio-economic milieu				
Travel time to Quebec City centre by car (minutes)	.086092	5.831	.016	1.089907
Euclidean distance to the nearest high school (metres) * Ratio of sale price ($) / lot size (square metres) * Apparent age of the property (years)	-1.852E-7	17.836	.000	1.000000
Travel time to the nearest regional-level shopping centre (minutes) * Apparent age of the property (years)	.006903	17.429	.000	1.006927
Vegetation and buyer-related attributes				
Vegetation on lot was an incentive to buy this home * Gender		6.467	.039	
Respondent of opinion poll is a woman	.865433	5.789	.016	2.376034
Respondent of opinion poll is a man	-.290229	.406	.524	.748092
Wooded area of adjacent properties (%) * Household income ($K)	.000549	33.205	.000	1.000549
Wooded area of adjacent properties * Buyer's household income < $40K (%)	.026088	6.286	.012	1.026431
Wooded area of adjacent properties * Buyer's household income > $80K (%)	-.015586	4.900	.027	.984535
Ratio of property assessed value ($) / Buyer's household income ($)	.424753	8.223	.004	1.529212

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