Hedonic Pricing Model – Open Space and Residential Property Values

Open Space vs. Urban Sprawl

As the American urban population decentralizes, economic growth has resulted in loss of open space. Urban planners and real estate developers often face a trade-off between developing and reserving open space. Developers hope to maximize the function of space, building residential and commercial sites to fulfill the needs of economic and population growth. Open space, however, performs important ecological and recreational functions. Public parks and forests can absorb carbon emissions and maintain humidity in the atmosphere. Open areas provide pleasant views or space for outdoor activities. However, these benefits are not immediate evident because these services are public goods without a market price. Therefore, this lack of monetary value prevents open areas from being appropriately considered in the cost-benefit analyses of public urban planning policies. Using data from the Minneapolis-St. Paul metropolitan area, Anderson and West (2006) estimate the effects of distance from open space on housing sales price with the hedonic pricing model. Since people in a competitive housing market are willing to pay more for homes with desirable attributes, the amenity value of open space can be analyzed in terms of housing sales price. Among houses with similar characteristics, the ones closer to open areas, as the model predicts, are supposed to have higher values.

Conceptual Framework

The hedonic pricing model estimates the value of each characteristic that defines a good by comparing the market prices among goods with different amounts of the attribute. Assume a good consists of a set of heterogeneous attributes. The market price of a certain good can thus be assumed as the sum of prices for each attribute defining the good. The function is

\[ P = f(x_1, x_2, ..., x_l) \]  

(1)

where \( P \) is the market price of the good and \( x_1, x_2, ..., x_l \) represent the attributes of which it is formed. The partial derivative of the hedonic price function with respect to a certain characteristic, \( x_l \), equals the marginal price of that characteristic, which represents the marginal willingness to pay.

Housing is essentially a good with plenty of characteristics that define it, such as total size and age. The price that the homeowner pays for a house is the sum of the prices of each of its characteristics.
Each attribute defining the house, therefore, has an implicit price. Anderson and West (2006) define a hedonic price function of a home \( h \) as

\[
P_h = f (S_h, N_h, A_h),
\]

(2)

where characteristics, \( x_s \), are structural attributes \( (S_h) \), neighborhood characteristics and location \( (N_h) \), and environmental amenities \( (A_h) \).

Two forms of the regression model exist: linear and double-log. Assuming the relationship between characteristics and price of the housing is linear gives

\[
P_{h} = b_{s} S_{h} + b_{n} N_{h} + b_{a} A_{h} + \varepsilon_{h},
\]

where \( b_{s}, b_{n}, \) and \( b_{a} \) are parameters and \( \varepsilon_{h} \) is the error term. The marginal willingness to pay for an additional unit of environmental amenities is \( b_{a} \). In the linear model, the marginal price for each additional unit remains constant. One major limitation is that this marginal price does not depend on the initial level of each explanatory variable. The second form is the double-log model, which transforms the Eq. (2) to

\[
\ln P_{h} = \beta_{s} \ln S_{h} + \beta_{n} \ln N_{h} + \beta_{a} \ln A_{h} + u
\]

where \( \beta_{s}, \beta_{n}, \) and \( \beta_{a} \) are parameters and \( u \) is the error term. Under log-log specification, one can measure how the changes in explanatory variables relate to the dependent variable in relative terms. The parameter \( \beta_{a} \) is the value of the elasticity of sales price with respect to the environmental amenities since

\[
\beta_{a} = \frac{\partial \ln P_{h}}{\partial \ln A_{h}} = \frac{\Delta P_{h}/P_{h}}{\Delta A_{h}/A_{h}}.
\]

(3)

Because most studies suggest that the relationship between environmental variable and price is nonlinear, so the logarithmic model is more frequently adopted than the linear version.

**Methodological Issues**

Like many other regression models, the hedonic price function poses two specific problems regarding the open space value based on Eq. (2):

- If real estate development depends on the property value, unobserved variables of home value that correlate with the quantity of open space exist. Causality could go from open space amenities to higher housing price or from an omitted variable to both. As a result, the Ordinary Least Squares (OLS) estimation could be biased.
- What if the open space is privately owned? The interdependence of uses of nearby parcels of land makes the number of privately owned open space endogenous to housing sales price.
If these problems are not solved, the omitted variable bias would occur. To address these issues, one typically uses fixed effect and instrumental variable approaches.

**Improved Econometric Model**

To control these unobserved variables, Anderson and West (2006) use a large sample of data and local fixed effects. Instead of taking the instrumental variables approach as in several other studies, they control potential omitted neighborhood characteristics with local fixed effects. With a significantly larger dataset, the scholars are able to specify fixed effects on a more effective geographic scale. Additionally, the open areas, such as public parks, golf courses, and cemeteries, in the sample are generally reserved as permanent open space. The issues above thus are not of great concerns here.

With the consideration above, Anderson and West (2006) formulate a hedonic function as follows:

\[
\ln P_{hi} = \alpha \ln X_{hi} + \beta Y_{hi} + \sum_{a \in A} \ln d_{a,hi}[\lambda_a + \theta_a S_{a,hi} + Y_a Z_{hi}] + \delta_i + \epsilon_{hi},
\]

where \(P_{hi}\) is the sales price of home \(b\) in block group \(i\); \(X_{hi}\) is a vector of continuous home structural attributes; \(Y_{hi}\) is a dichotomous vector of home structural characteristics and month-of-sale dummy variables; and \(\alpha\) and \(\beta\) are parameter vectors to be estimated. \(A\) is the set of environmental amenities, so \(d_{a,hi}\) is the distance of the nearest amenity of type \(a\) and \(S_{a,hi}\) is the size. \(Z_{hi}\) is a vector of covariates that affect the value of proximity to amenities, and \(\lambda_a, \theta_a, \text{and } Y_a\) are two parameters and a parameter vector to be determined for each \(a\). \(\delta_i\) is a local fixed effect, and \(\epsilon_{hi}\) is the error term.

With the equation above, Anderson and West (2006) thoroughly explore the variables for each vector. \(P_{hi}\) is 1997 single-family home sales price from Minnesota. Continuous home structures, \(X_{hi}\), feature the lot size, total square feet, number of bathrooms, and age of home, as these are the most common attributes of the house itself that homebuyers look for. Additionally, a dummy variable measures if a home has a fireplace, and another dummy variable represents month-of-sale to control for any seasonality in sales price, both of which form the vector \(Y_{hi}\). The environmental amenities include neighborhood parks, special parks, golf courses, cemeteries, lakes, and rivers, all of
which are public spaces that generally open permanently. The distance, $d_{a,hi}$, and size, $S_{a,hi}$, of each neighboring open space are taken into consideration.

When purchasing a home, people also consider nearby attributes, such as density, income, crime rate, distance to the Central Business District (CBD), and demographics of the neighborhood. Not only do these neighborhood characteristics affect home values, but they also are correlated to how much residents appreciate the open space nearby. For example, for neighborhoods with a higher population density or closer to the CBD, homebuyers might be willing to pay more for a home near a neighborhood park. The amenity value probably rises within areas where families have younger children or mostly older people reside. Studies suggest that high-income homeowners pay higher prices for the proximity to open space than low-income homeowners. In addition, on an intuitive level, one might assume that people nearby might not enjoy activities outside as often in neighborhoods with an increased crime rate. These attributes therefore are expressed as covariates, $Z_{hi}$, of the proximity to the environmental amenities.

**Solutions and Predictions**

One can examine the relationship between housing sales price and distance to environmental amenity $a$ by taking the partial derivative with respect to $\ln d_{a,hi}$. This gives the elasticity of home value regarding distance to amenity $a$ as

$$\frac{d \ln P_{hi}}{d \ln d_{a,hi}} = \lambda_a + \theta_a S_{a,hi} + \gamma_a Z_{hi}$$

(5)

i.e., the percentage change in sales price is correlated to the percentage change in distance to open space $a$. If the relation between proximity to the amenity and home value is positive, the elasticity is negative, i.e., sales price increases as distance falls. The elasticity in Eq. (5) depends on amenity size and the covariates in vector $Z_{hi}$. One might also predict that a larger size of public open space would increase the value of proximity to the amenity.

For each vector $Z_{hi}$, a negative $\gamma_a$ means that the value of proximity to amenities rises with an additional unit in that particular attribute. A covariate is the product of two correlated variables, for example, the covariate of density and distance to amenity $a$ equals $\text{density} \times \ln d_{a,hi}$. Theory suggests that linear covariates perform better than logged ones. To simplify the coefficients for covariates, the scholars normalize the vector $Z_{hi}$ as the following linear form:
\[ Z_{hi}^* = \frac{(Z_{hi} - \bar{Z})}{\bar{Z}} \]

where \( \bar{Z} \) is the sample mean of the covariate. One can apply the local fixed effect here to calculate the sample mean within each block group.

**Implications**

This hedonic pricing model has important implications for land use and urban planning regulation policies. With rising economic growth and urban sprawl, several studies have used the hedonic model to evaluate amenities or externalities correlated to home value. Some studies focus on the distance to different types of open space; others examine the relationship between the quantity of nearby open areas and home values. The methodology presented in this paper measures the amenity value not only by open area type, but also by neighborhood and location of a home, which include variables, such as proximity to CBD, density, and crime rate. In addition, the model controls for unobserved spatial variables with local effects. These results could provide significant information about spatial context to urban planners and real estate developers. While designing policies to protect open areas or implement land-use regulations, they might also include the surrounding characteristics in the cost-benefit analysis to get the comprehensive amenity value.

**Possible Further Extensions**

Although this is an extended version of previous hedonic pricing regression on amenities, a few limitations still exist. The model only measures the amenity value of the nearest open space to a neighborhood. There might be some distant areas that affect home values as well, but the study does not include this possibility. We can address this issue by studying open areas within a scale of distance to each block group. Additionally, local fixed effects create a few problems. The block group might overlap neighborhood boundaries or lie within neighborhoods, which results in biased estimation. Finally, other unobserved covariates might exist other than the ones Anderson and West (2006) have covered in vector \( \mathbf{Z}_{hi} \), but fixed effects do not control for these omitted covariates. For example, nearby school districts could influence both house sales price and appreciation of nearby environmental amenities.

**Reference:**