Hedonic Approach – A Quick Summary

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The Concept. There are two ways for measuring the demand for environmental goods, namely revealed preference and stated preference. The first one is determined by observing actual choices by individuals and using the information to infer the relation between money and market goods. Fall into this category is travel cost method and hedonic approach. The stated preference, on the other hand, is determined by asking individuals how much worth an environmental good is. This second approach is called contingency valuation method.

Hedonic price technique was developed by Griliches (1971) and Rosen (1974). In environmental economics it has been used to determine how the price of a conventional good varies in response to changes in a closely related environmental good. For example, housing price is strongly affected by the quality of air surrounding the area. Individual decision to buy a house is therefore a function of his expected exposure to pollution. Pollution is a "bad", and individual is willing to pay more for the housing to get rid of it, that is, if the air quality is improved. The hedonic approach allows us to measure this "willingness to pay". In other words, this approach is a way to quantify the monetary value of the air quality improvement (e.g. Harrison and Rubinfeld, 1978). It has the advantage of capturing all possible effects of the quality change related to, for example, respiratory diseases, visibility, and ornamental damages (Freeman, 1993). We will focus the remaining discussion to this case of measuring air quality improvement.

This approach involves four steps. The first step is the estimation of a hedonic housing price function. A second step is the isolation of the effect of the air quality from the effects of other characteristics on the housing price. Technically, this means the calculation of the marginal price of housing with respect to air quality changes. Next, this marginal value is regressed on income and the air quality measure. The function used reflects the sensitivity of marginal willingness to pay with respect to changes in air quality[1]. Finally, we can obtain the measure of total willingness to pay by aggregating all the marginal willingness to pay for all individuals over the range of quality change. We show this approach formally in what follows.

We assume that consumer takes into account all housing characteristics when making her purchase. All the variations in housing characteristics are capitalized into housing prices. In addition, there are sufficient variations in air quality across locations, housing type, and all characteristics that are considered. Finally, we assume that the market is in equilibrium (Freeman, 1993; Khanna, 2000).

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[1] This step is optional, depending on our goal and the price functional form we are using. In our model (next section) for example, this step can be taken care by restriction on parameters so as to transform the function to other more restricted function. Estimation results will show the comparison of WTP sensitivities. On the other hand, we can use this step to infer more information. For example, log-log form for WTP function provides information of pollution elasticity and income elasticity of the marginal willingness to pay.

Suppose an individual is maximizing a utility function $u(S,Q,X)$ given a constraint $Y = X + P(S,Q)$, where S is the characteristics attributed to housing, Q is an index of air quality, X is a composite commodity, Y is total income, and P is the housing price. The first-order conditions of this maximization yield (i) ${}^{u_S}\!/_{u_X} = P_S$ and (ii) ${}^{u_Q}\!/_{u_X} = P_Q$, where subscript denotes partial derivative of the associated variable with respect to it. Both right hand sides are sometimes referred to as inverse demand functions. The first one shows the effect of the composite commodity on the housing price; while the second first-order condition is the implicit marginal price of air quality. It shows how much the individual is willing to pay for additional improvement in air quality (i.e. additional reduction in pollution level), given other characteristics constant. In other words, it is the rent differential for a small change in air quality. This algebraic procedure involves the first two estimation steps.

That is, econometrically, we first estimate the function $P=P(S,Q)$, then take its derivative with respect to Q. Denote this as W (stands for willingness to pay). We next regress this dependent variable on Q and Y. This is the marginal willingness to pay function to investigate the sensitivity of willingness to pay. Here, by assuming weak separability of the utility function, we can write it as $W=f(Q,Y)$. Finally, integrating this function over the change in Q, $\sum \int_{Q_1}^{Q_0} f dQ$ that gives us the total willingness to pay and implies the total benefits from air quality improvement in the area.

Functional form. In this section we discuss a framework that can be used to obtain a measure of improved air quality in Los Angeles area. There have been numerous studies with hedonic approach undertaken to measure quality improvement in environmental field. One of the early studies is Wieand (1973). He employs a linier price function involving ten independent variables. He finds that his estimated coefficients of pollution variables are not significant. Harrison and Rubinfeld (1978), on the other hand use a semilog price function applied to Boston metro area. They find that this form of function provides a slightly better fit (all coefficients are significant). More recently, Graves et al (1988) and Chattopadhyay (1999) use a quadratic Box-Cox model. This function is more flexible than translog, log-linier, semilog, linier, quadratic, and semilog quadratic[2]. However, the choice of included variables greatly affects the result. In fact, Cassel and Mendelsohn (1985) has pointed out that when the goal is to obtain the best estimates of parameters rather than the best fit, this function may not be preferable. Having this in mind, Zabel and Kiel (2000) choose to estimate linear, log-linear, and log-log models. On the other hand, Cropper et al (1988) compare all the functional forms mentioned above and find that linear Box-Cox outperforms other functional forms including the quadratic Box-Cox. Given the considerations in these studies, we suggest estimating the hedonic price function using both linear Box-Cox and quadratic Box-Cox model and comparing the mean percentage errors. (However, in the case that some attributes are unobserved, linear Box-Cox is suggested). Recalling our implicit utility- and price function in the previous section, our unrestricted quadratic Box-Cox form is therefore:

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[2] See a discussion of this function in Spitzer (1982).

$$P(S,Q)^{\theta} = \alpha_0 + \alpha_Q Q^{\lambda} + \sum_{i=1}^{k} \alpha_i s_i^{\lambda} + 0.5\gamma_{QQ} Q^2 + 0.5 \sum_i \sum_j \gamma_{ij} s_i^{\lambda} s_j^{\lambda} \qquad (1)$$

where $P(S,Q)^{\theta} = [(P(S,Q))^{\theta} - 1)]/\theta$ and $Q^{\lambda} = (Q^{\lambda} - 1)/\lambda$ (2)

s_i = 1,…,k is the characteristics attributed to housing prices (elements of vector S). When γ_{QQ} and γ_{ij} are zero, the function reduces to linear Box-Cox[3]. In addition to this function, we can use either Diewert function or translog function for utility, as the following:

$$u(S,Q,X) = X^{.5} + (\eta_Q + \delta_Q C + \tau_Q R)Q^{.5} + \sum_{i=1}^{k} (\eta_i + \delta_i C + \tau_i R) s_i^{.5} + 0.5\beta_Q Q + 0.5 \sum_{i,j=1}^{k} \beta_{ij} s_i^{.5} s_j^{.5} \qquad (3)$$

$$u(S,Q,X) = \log X + (\eta_Q + \delta_Q C + \tau_Q R)\log Q + \sum_{i=1}^{k} (\eta_i + \delta_i C + \tau_i R)\log s_i + 0.5\beta_{QQ}(\log Q)^2 + 0.5 \sum_{i,j=1}^{k} \beta_{ij} \log s_i \log s_j \qquad (4)$$

where C and R represent demographic factors (e.g. number of children and race) associated with the individual (not the house) affecting her decision to buy housing. In (4) it is clear that these demographic factors affect the marginal utility of housing attributes. Bartik (1987) points out that simultaneous determination of marginal price and the level of attributes may lead to a problem of endogeneity. To deal with it, we can use a 3SLS with some household attributes (e.g. income and income squared) as instrumental variables. Using a linear Box-Cox price function and Diewert utility function applied to (i) and (ii) will result in the following specification:

$$\alpha_i P^{1-\theta} s_i^{\lambda-1} = (X/s_i)^{.5} (\alpha_i + \delta_i C + \tau_i R + \sum_{j=1}^{k} \beta_{ij} z_j^{.5} + \varepsilon_i) \qquad (5)$$

where now, with a slight abuse of notation, assume Q is in vector S, that is i,j=1,…,k,Q. We can see that after estimating the inverse demand parameters, we can obtain the estimated utility parameters as well. Next, we can calculate the marginal willingness to pay function by taking the derivative of P with respect to Q and compute the value using the estimated parameters. Finally, we can obtain the total willingness to pay by integrating this function[4]. This implies the benefit of changes in air quality.

Dependent variable. Harrison and Rubinfeld (1978) use median (instead of mean which is distorted in the presence of outliers) value of home-owner occupied homes as dependent variable, since they focus their study on owner market. Wieand (1973), on the other hand argues that the correct dependent variable should be housing value per unit of

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[3] We can also impose other restrictions that transform it into linear, semilog, log-log, or quadratic.

[4] Here, we may not need to execute third step. See fn. 1. Yet, estimating the WTP function separately may allow more straightforward investigation. Also, we can obtain the "demand curve for clean air".

land, since housing price is very sensitive to land's price[5]. Close to Harrison and Rubinfeld, Brookshire et al (1982), Graves et al (1988), Murdoch and Thayer (1988), Chattopadhyay (1999) choose home sale prices at nominal rates. Also, Zable and Kiel (2000) use deflated value of the house. We share this view, that is, we use the median selling price of the housing, since the data for it is more accessible[6].

Independent variables. Explanatory variables in the price function may include structural and neighborhood characteristics, accessibility, and an index for air quality. Studies have been using various kind of structural characteristics such as number of rooms, number of stories, garage, pool, basement, air conditioning, fireplace, age of the house, land size, floor area, living room area, etc. (see e.g. Wieand, 1973; Harrison and Rubinfeld, 1978; Brookshire et al, 1982; Bartik, 1987; Cropper et al, 1988, Graves, 1988, Murdoch and Thayer, 1988, Chattopadhyay, 1999; Zable and Kiel, 2000). Clearly, we do not need all these structural characteristic variables, since some of them may pose multicollinearity. However, omitting relevant variables may yield bias as well (Davidson and MacKinnon, 1993).

Neighborhood characteristics may include racial and ethnic composition (Harrison and Rubinfeld, 1978; Brookshire et al, 1982; Murdoch and Thayer, 1988, Graves et al, 1988, Cropper et al, 1988), teacher-pupil ratio in public school (Wieand, 1973; Harrison and Rubinfeld, 1978, Brookshire et al, 1982, Graves et al, 1988, Chattopadhyay, 1999), proportion of low-income status (Harrison and Rubinfeld, 1978), persons per dwelling unit (Wieand, 1973), average family income (Harrison and Rubinfeld, 1978), etc. Again the choice of these variables should be taken with cautious, since it may result in multicollinearity or biased estimation due to including irrelevant variables and/or omitting relevant variables[7].

Accessibility could be approximated by the distance of the housing area to highway, industry parks, central business district, or nearest beach (see e.g. Wieand, 1973; Harrison and Rubinfeld, 1978, Murdoch and Thayer, 1988). Surely, train station, bus terminal can also be considered.

Finally, and most importantly, is the variable to represent air quality. Wieand (1973) uses the average concentration of suspended particulates, sulfur trioxide, and sulfur dioxide. Harrison and Rubinfeld (1978) choose level of nitrogen oxide, Chattopadhyay (1999) uses sulfur dioxide and particular matter (PM-10), Zabel and Kiel (2000) choose nitrogen dioxide, ozone, sulfur dioxide, and total suspended particulate. Graves et al (1988) use total suspended particulate along with visibility. Our model we developed earlier shows a single measure of air quality (Q). In this case, we can follow Harrison and Rubinfeld to use NOX as proxy for air quality[8]. Clearly, the model can be adjusted to allow for multi variable representing air quality, with special attention to potential multicollinearity. Alternatively, we can create one variable as an index of some

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[5] Wieand claim that the Census average value of housing is merely a total family expenditures on housing, not the unit price of housing, and therefore negatively related to the elasticity of demand for housing.
[6] The problem is, this value is sensitive to unusually large numbers of first-time buyers. In this case, we can use median price per square foot. The data can be obtained from American Housing Survey.
[7] Most of the data for these neighborhood characteristics could be obtain from U.S. Cencus.
[8] Or, of course, other substance that is more relevant representing the condition in Los Angeles. A report says that the most hazardous pollutant in L.A. air is 1,3-butadiene (see Waxman, 1999).

pollutants[9]. In addition, we will enter the squared value of this variable, to allow for some "tolerance" of pollution, before the level at which the individual is willing to pay for its reduction.

Other econometrics issues. In previous studies, identification and endogeneity problem are important aspects that need careful attention. Endogeneity may due to simultaneously determined characteristics variables. In this present context, fortunately, we can avoid this problem by employing a 3SLS as discussed above. In addition, problem of identification depends on how we treat the marginal willingness to pay function. The nonlinear nature of (5) in fact, makes the system of equation identifiable. If, on the other hand, our goal is to show the demand curve for air quality through estimating the willingness to pay function, we may need to consider a "bid" function involving new variables not included in the price function (Freeman, 1993). These variables may include, for example, commuting costs to and from the area (Cassel and Mendelsohn, 1985). Otherwise, if we fail to address this problem, we will redundantly obtain the same coefficients as in the first step. This happens because the dependent variable, i.e. marginal willingness to pay, is not observed and simply is an estimated value from the price function.

Another issue is heteroscedasticity. The error term in (5) reflects unobserved tastes of the individual as well as measurement inaccuracy. To address the possibility of heteroscedastisity, we can multiply the left- and the right hand side of (5) by $(X/s_i)^{-.5}$.

Reference

Bartik, T.J. 1987. The Estimation of Demand Parameters in Hedonic Price Models. *Journal of Political Economy*. 95(1), 81-88.

Brookshire, D.S., M.A. Thayer, W.D. Schulze, R.C. d'Arge. 1982. Valuing Public Goods: A Comparison of Survey and Hedonic Approaches. *American Economic Review*. 72(1), Mar, 165-177.

Cassel, E. and R. Mendelsohn. 1985. The Choice of Functional Forms for Hedonic Price Equation: Comments. *Journal of Urban Economics*. 18, 135-142.

Chattopadhay, S. 1999. Estimating the Demand for Air Quality: New Evidence Based on the Chicago Housing Market. *Land Economics*. 75(1), Feb, 22-38.

Cropper, M.L. L.B. Deck, and K.E. McConnell. 1988. On the Choice of Functional Form for Hedonic Price Function. *Review of Economics and Statistics*. 70(4), Nov, 668-675.

Davidson R. and J.G. MacKinnon. 1993. *Estimation and Inference in Econometrics.* Oxford University Press.

Griliches, Z. 1971. Introduction: Hedonic Prices Revisited. in Z. Griliches (ed), *Price Indexes and Quality Change*. Harvard University Press.

Freeman, M. III. 1993. *The Measurement of Environmental and Resource Values.* Resource for the Future.

[9] In our L.A. case, this could be the composite of 1,3-butadiene with the next two most harmful substances: formaldehyde and benzene (see Waxman report). The data itself can be obtained from Environmental Protection Agency.

Graves, P., J.C. Murdoch, M.A. Thayer, and D. Waldman. 1988. The Robustness of Hedonic Price Estimation: Urban Air Quality. *Land Economics*. 64(3), Aug, 220-233.

Harrison, D. Jr. and D.L. Rubinfeld. 1978. Hedonic Housing Prices and the Demand for Clean Air. *Journal of Environmental Economics and Management.* 5, 81-102.

Khanna, M. 2000. Lecture Notes for Environmental Economics. University of Illinois at Urbana Champaign. Unpublished/manuscripts.

Murdoch, J.C. and M.A. Thayer. 1988. Hedonic Price Estimation of Variable Urban Air Quality. *Journal of Environmental Economics and Management*. 15, 143-146.

Rosen, S. 1974. Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy*. 82, Jan/Feb, 34-55.

Spitzer, J.J. 1982. A Primer on Box-Cox Estimation. *Review of Economics and Statistics.* 64(2), May, 307-313.

Spitzer, J.J. 1984. Variance Estimates in Models with the Box-Cox Transformation: Implications for Estimation and Hypothesis Testing. *Review of Economics and Statistics.* 66(4), Nov, 645-652.

Zabel, J.E. and K.A. Kiel. 2000. Estimating the Demand for Air Quality in Four U.S. Cities. *Land Economics*. 76(2), May, 174-194.

Waxman, H.A. (Rep). 1999. Exposure to Hazardous Air Pollutants in L.A. Minority Staff Report, Commission on Government Reform, U.S. House of Representative.

Weiand, K.F. 1973. Air Pollution and Property Values: A Study of The St. Louis Area. *Journal of Regional Science.* 18(1), 91-95.