Environmental Values Revealed through Property Values (Raymond Palmquist, North Carolina State University, presiding)

THE ROLE OF OPTIMIZING BEHAVIOR IN WILLINGNESS-TO-PAY ESTIMATES FOR AIR QUALITY

HOLGER SIEG, V. KERRY SMITH, H. SPENCER BANZHAF, AND RANDALL WALSH

Revealed preference models used in nonmarket valuation have, at times, overlooked potentially important implications of the assumption of optimizing behavior in measuring individuals' values for amenities. Epple and Sieg (1999a) have developed a new empirical framework that can be adapted to illustrate this general point by using the spatial equilibrium conditions to identify and estimate preference functions that include local and environmental public goods. After outlining our modifications to their framework in the next section, we illustrate how it can be used to estimate the marginal willingness to pay for reducing air pollution in southern California. Estimates based on a hedonic model are also presented for comparative purposes.

Our preliminary estimates of marginal willingness to pay (WTP) measures for reducing ozone (in 1990 dollars) from the spatial sorting model are between 9% and 32% smaller (depending on the county and air pollution measure used) than the hedonic estimates. These estimates move consistently with the averages computed from the hedonic model's point estimates for each housing sale in the thirty-six school districts included in this preliminary analysis. These comparisons are certainly not tests for differences across models. However, they do suggest recognizing the discreteness in local public goods, and site-specific amenities may well introduce an important new restriction, implied by the sorting equilibrium framework, to the measurement of consumers' values for improvements in air quality.

Spatial Equilibria and the Valuation of Amenities

Rosen's description of the conditions for consumers' locational choices emphasized that the optimal location in characteristic space occurs where the WTP and price surfaces are tangent. This framework relies on a spectrum of types of houses so the characteristic space can be treated as continuous. In practice, people choose among an array of houses with differing characteristics and, more importantly, select one of a finite set of communities to obtain different amounts of locally provided public goods and environmental amenities. Under these conditions, it may be desirable to separate the task of developing a price index for the heterogeneous houses from the task of describing these locational decisions. The equilibrium can be treated as a sorting of a continuum of people among each of the communities providing different amounts of the public goods and amenities.[1]

Holger Sieg is assistant professor of Economics, Duke University. V. Kerry Smith is university distinguished professor, North Carolina State University and Resources for the Future University Fellow. And H. Spencer Banzhaf, and Randall Walsh are graduate students, Department of Economics, Duke University.

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[1] Ross has recently attempted to incorporate these concerns within a conventional hedonic framework.

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To describe this process, Epple and Sieg adapt earlier models by Epple and Romer and Epple and Platt. They describe individual heterogeneity using a joint distribution of endowed income (y) and a taste parameter (α) for public goods that is bivariate log normal with correlation λ. Individuals have preferences over community-specific public goods, g_j, (including air quality), a local housing good, h_j, and a composite numeraire good, b, with price normalized to unity. The gross-of-tax price for a unit of housing in community j is given by p_j. Individuals maximize utility subject to a budget constraint ($y - p_j h_j - b = 0$). Preferences are assumed to satisfy the "single crossing property" with respect to y and α. This means that iso-utility curves in the (p, g) plane cross only once and, in this case, that the lower income locus has a smaller slope. Single crossing implies that equilibrium allocations will satisfy three conditions: boundary indifference, stratification, and ascending bundles. The first condition implies that individuals on the boundary are indifferent between adjacent communities j and $j + 1$. Stratification implies that for each value of α, residents of community j will consist of those whose income falls in the interval defined by: $y_{j-1}(\alpha) < y < y_j(\alpha)$, where $y_j(\alpha)$ is the function implicitly defined by the boundary indifference condition. Ascending bundles implies that for any two communities i and j with $p_i > p_j$ then $g_i > g_j$ if and only if $y_i(\alpha) > y_j(\alpha)$. We can reinterpret the difference between $y_J(\alpha)$ and $y_i(\alpha)$ as an equivalent variation measure for moving a household from the community with the largest g and p, J, to community i. The ordering of these measures is, by construction, equivalent to the ordering described in the ascending bundles property.[2]

Table 1. Hedonic Property Value and Sorting Equilibrium Models

Independent Variables	Hedonic Specification: Temporal Av.	Distance Av.
Orange	0.376	0.372
	(71.57)	(82.18)
Riverside	−0.151	−0.142
	(−46.36)	(−49.96)
Bathrooms	0.062	0.062
	(24.88)	(28.89)
Age	−0.002	−0.002
	(−34.39)	(−36.67)
Sq. ft-bldg.	0.004×10^{-1}	0.004×10^{-1}
	(159.55)	(36.77)
Sq. ft-lot	0.004×10^{-4}	0.004×10^{-4}
	(34.68)	(36.77)
Fireplace	0.082	0.084
(=1)	(35.94)	(39.77)
(Pool)	0.049	0.050
(=1)	(19.56)	(21.46)
Average math	0.003	0.002
score	(6.92)	(6.66)
Coastal	0.074	0.078
(=1)	(24.74)	(28.37)
Ridge	−0.102	−0.098
(=1)	(−38.02)	(−39.73)
Ozone	−0.841	−1.017
	(−17.58)	(−23.28)
Number of observations	153,474	170,750
σ_n	0.070	0.115
σ_ϵ	0.331	0.326
r	0.043	0.111

Epple-Sieg Parameter Estimates[a]	
$\mu_{\ln(y)}$	10.50**
$\sigma_{\ln(y)}$	0.72**
λ	0.03
$\mu_{\ln(\alpha)}$	−0.59
$\sigma_{\ln(\alpha)}$	0.37**
ν	0.96**
ρ	−0.07**
Ozone	−0.60

Note: The numbers in parentheses for the second and third columns are the t-ratios for the null hypothesis of nonassociation.
[a] To economize on space, we report the primary parameters estimates, mean and standard deviations for $\ln(y)$, $\ln(\alpha)$ and their correlation (λ), and the parameter for ozone. The coefficient for math score was normalized to unity and the parameters B and η were set to values consistent with housing demand studies $B = 0.287$ and $\eta = -0.30$.
** = significant at least at 1% level.

The hedonic approach relies on the existence of a continuous array of heterogeneous hous-

[2] We can interpret $y_j(\alpha)$ as an expenditure function. The boundary indifference condition is a point where the WTP for community $j + 1$ compared to community j is 0. Therefore,

$$WTP = y(\alpha, p_j, g_j, U_0) - y(\alpha, p_{j+1}, g_{j+1}, U_0).$$

Along the boundary indifference locus $WTP = 0$ and hence,

$$y_j(\alpha) = y(\alpha, p_{j+1}, g_{j+1}, U_0).$$

Stratification implies an ordering of

$$y_1(\alpha) < y_2(\alpha) < \ldots, < y_J(\alpha).$$

Subtracting $y_J(\alpha)$ from every element we have

$$y_1(\alpha) - y_J(\alpha) < y_2(\alpha) - y_J(\alpha) <, \ldots, < 0.$$

If we define the utility realized in community i, ($i < j$) by an individual with a fixed level of y and α as U_i, there exists a reference utility level, $\tilde{U}_j$ defined by the following condition:

$$y(\alpha, p_i, g_i, U_i) = y(\alpha, p_J, g_J, \tilde{U}_i).$$

This means that the ordering associated with stratification and ascending bundles is an ordering of the equivalent variation measure for movement from community J to community i. The Epple-Sieg estimator can be interpreted as using that EV ordering in the stratification that clusters households into communities.

Table 2. Comparison of Marginal Willingness to Pay Across School Districts for Ozone Reduction: Sorting Equilibrium versus Hedonic Estimates (1990)

County	Number of School Districts	Epple-Sieg Sorting Equilibrium	Hedonic Property Value[a]	
			Temporal Average	Distance Average
Orange	15			
Range		125.44–548.97	157.20–490.75	204.12–555.54
S[b]		—	0.843	0.711
Riverside	12			
Range		52.23–225.17	120.65–244.13	157.33–300.17
S		—	0.916	0.902
San Bernardino	9			
Range		122.46–269.82	164.95–352.18	202.07–424.76
S		—	0.883	0.850

[a] The hedonic estimates use Porterba's (1992) estimate for annualization and are adjusted to 1990 dollars using the price index for owner's equivalent rent of their primary residence.

[b] S is the Spearman rank correlation statistic for comparing the Spatial Sorting Equilibrium and Hedonic Equilibrium.

es, distinguished by physical attributes and by the site specific local public goods (including amenities). Household movement among this continuum of houses reveals their marginal valuations for the characteristics assumed to distinguish the houses but not the demand for each type of house. As a consequence, it does not yield these kinds of predictions and cannot incorporate them into the estimation.

To parameterize the spatial equilibrium model, we assume that preferences are defined by the indirect utility function given below:

$$(1)\quad V(\alpha, y, g_j, p_j) = \left(\left[\alpha g_j^{\rho} + \left[\exp\left(\frac{y^{1-\nu}-1}{1-\nu}\right) \times \exp\left(-\frac{Bp_j^{\eta+1}-1}{\eta+1}\right)\right]^{\rho}\right]\right)^{1/\rho}.$$

Given this specification, the set of households living in community (j) is given by

$$(2)\quad C_j = \left[(y, \alpha)\,|\,K_{j-1} \le \ln(\alpha) - \rho\left(\frac{y^{1-\nu}-1}{1-\nu}\right) \le K_j\right]$$

where

$$K_j = \ln\left(\exp\left(-\frac{\rho}{1+\eta}(Bp_{j+1}^{\eta+1}-1)\right) - \exp\left(-\frac{\rho}{1+\eta}(Bp_j^{\eta+1}-1)\right)\right) - \ln(g_j^{\rho} - g_{j+1}^{\rho}).$$

Given these assumptions, we can estimate the model's parameters using a two-step procedure. In the first step, we estimate a subset of the parameters by matching the income distributions of the communities in the sample predicted by the spatial equilibrium model with their empirical counterparts. In the second step, we estimate the remaining parameters by matching the predicted level of the public goods provided in each community with an index of observed amenities.[3]

The model also implies a distribution of willingness-to-pay values for increases in public goods in each community.[4] Equation (2) defines the set of (y, α) pairs that comprise each community. For each (y, α) pair, we expect a different WTP. Indeed, an exogenous change in air quality would give rise to a new sorting of households, and thus one can distinguish partial and general equilibrium WTP measures. To illustrate the model in simple terms, comparable to what is available from

[3] See Epple and Sieg (1999a) for details.

[4] It is also possible to exploit restrictions derived from majority rule in the estimation procedure. See Epple and Sieg (1999b).

a hedonic price function, we have computed the marginal willingness to pay for each (y, α) pair using the virtual price for air quality derived from equation (1). Integrating over each community's population yields an estimate of the average of the members' marginal WTP.

Because the hedonic model assumes an exact match between a consumer and a house in each community, there is one marginal value of air-quality change for the owner of each house. This value can be recovered from the slope of the hedonic price function, following the Rosen logic.

Thus, our analysis considers two of the various approaches that can be used to estimate the marginal willingness to pay for air-quality improvements. Each approach relies on a different set of assumptions describing the constraints to consumer choice. They also differ in the extent that these assumptions are imposed in estimation. For example, most hedonic studies treat community-specific amenities as exogenous. This assumption has been criticized recently by Chay and Greenstone. In contrast, the locational equilibrium approach acknowledges the potential endogeneity of housing prices and local public goods and uses functions of the ranks based on income as instrumental variables in the estimation. This procedure can be justified by appealing to the ascending bundles property of the underlying equilibrium model. A comparison of the estimates implied by each approach provides one way to consider the importance of the different assumptions used in each method.

Data and Results

The example we use to compare the spatial sorting and hedonic methods considers actual sales of residential properties in three counties in southern California (Orange, Riverside, and San Bernardino). We assembled from a commercial vendor (Transamerica Intellitech) all of the sales between 1987 and 1995. These data were filtered to eliminate nonarm's-length transactions and what appeared to be erroneous observations and merged with information on ambient air-pollution readings in the year of sale for the three closest monitors to each home.[5] This process yielded over 250,000 observations. The school district (SD) boundaries were used to define communities for the sorting equilibrium. To assure consistency between the sorting equilibrium estimates and the hedonic analysis, we limited the sample to sales in the thirty-six SDs.[6] We selected the SDs to correspond approximately to the air shed for these three counties, by using topographic maps to identify the ridge line. This sample restriction also limits the measurement error associated with the attachments from a limited number of monitors to the homes in the outer reaches of Riverside and San Bernardino counties. Data are available by monitor and year for several measures of ozone and PM_{10} (particulate matter less than 10 microns diameter) from the California Air Resources Board. Because this analysis is an early report of a larger effort, we concentrated on transactions between 1988 and 1994 and use the average of the top thirty (in a year at a monitor) of the one-hour daily maximums for the ozone readings.[7]

These counties have been among the most polluted in the United States (see Portney et al.). Ozone is the most important reason for their non attainment status. Over this period, they have experienced substantial improvements, as have the other non-attainment areas in the United States (see figure 1 in Henderson as an example for the United States as a whole). The community local public good included in the model is a measure of performance from standardized test scores for each SD using the 1992–93 California Learning Assessment System Grade Level Performance Assessment test. Each student taking this exam is assessed at one of six performance levels (with six the highest level). We investigated several measures and found math scores to be the most plausible measure of education quality. School District income distributions were taken from estimates developed by the National Center for Education Statistics and School District Data book. These data include a special tabulation of the 1990 census income distributions by SD.

[5] The housing sales and pollution data provide the latitude and longitude for each home and station. It is possible to compute based on these records the distance to sites with data in the year of the sales. We are currently exploring the influence of kriging (e.g., spatial averaging) as an alternative basis for linking readings to each home.

[6] The criterion for screening transactions included each of the following deletions: the lowest and highest 1% of sales prices by district; observations with less than one or greater than twenty bedrooms; observations with less than one or greater than fifteen bathrooms; observations where the square feet of the building is greater than four times the square feet of the lot; observations with less than 250 or more than 10,000 square feet in the building; properties with lot square footages less than 500 or more than 10,000. A listing of the included school districts is available from the authors.

[7] Henderson (1996) found that averaging of the readings offered a more reliable basis for measuring changes in ozone.

We estimated the parameters of consumers' preferences based on the SD-specific income-distribution quartiles using the same logic outlined in Epple and Sieg (1999a). To initiate this process, housing prices were estimated as SD-specific fixed effects after controlling for the number of bathrooms, age of the home, square feet of the building, square feet of the lot, and presence of a fireplace and a pool. The analysis used a log linear specification for the continuous measures (size of house, lot, and age entered as log and log squared; all other attributes were qualitative variables) and sale-year fixed effects. The three-year centered average ozone and average math scores by SD are the community-specific public goods. While the actual patterns of p_j and estimates for g_j (using a linear index for education and the ozone concentrations) will never satisfy the ascending bundles condition exactly, our findings are comparable to the experience Epple and Sieg (1999a) report for their Boston application, with a little over 20% rank violations. Estimates for the model's structural parameters are given in the lower panel of table 1. Although the ozone measure is not significant, its sign is consistent with theoretical expectations.

The columns labeled (1) and (2) in table 1 report our estimates for a semilog hedonic specification, treating the sale year as a fixed effect.[8]
In addition to the structural characteristics and ozone measure, we include the average math score described earlier and two other sets of qualitative variables for locational attributes. One identifies the counties (i.e., Orange and Riverside, with San Bernardino the omitted category). The second corresponds to qualitative variables for school districts along the coast or along the ridge line. For this second group, the attachments of ozone readings are less likely to capture adequately the air quality and other aspects of the location (e.g., access to the coast as an amenity in addition to better air quality and longer commuting distance in addition to poorer air quality). The two equations are distinguished by the ozone measure. In the first column, we consider the centered average (across years) of the nearest monitor readings. The second column uses a distance-weighted average of the three closest readings for the sale year. In all cases, the variables' coefficients are highly significant and consistent with prior expectations. The last aspect of our preliminary findings is reported in table 2 and concerns the marginal willingness to pay for a 10% reduction in ozone readings. The range of values across SDs for the marginal willingness to pay is remarkably consistent between the two approaches. The Spearman rank correlation (labeled S) indicates close correspondence between the ranking of sorting and hedonic estimates across the SDs in each county. The hedonic estimates range from \$120 to \$555 across SDs. Linear extrapolation of the estimated marginal price from the hedonic would imply that these are upperbounds for the correct incremental WTP. The sorting equilibrium is also approximating the incremental WTP.

[8] Cropper, Deck, and McConnell found the semilog specification to have the lowest bias in measuring marginal WTP when the specification of the hedonic price function omitted important housing or site attributes.

Implications

Both the hedonic and the sorting equilibrium model require an equilibrium condition to identify the parameters of interest. The sorting equilibrium framework uses the conditions for household movement among a discrete set of communities to estimate preference parameters. It allows the extensive margin conditions for an equilibrium to be used within a revealed preference model and incorporates the effects of unobserved heterogeneity in tastes for public goods into the recovery of nonmarket values. Our empirical findings offer an illustration of how equilibrium conditions can be used directly in estimating nonmarket values.

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