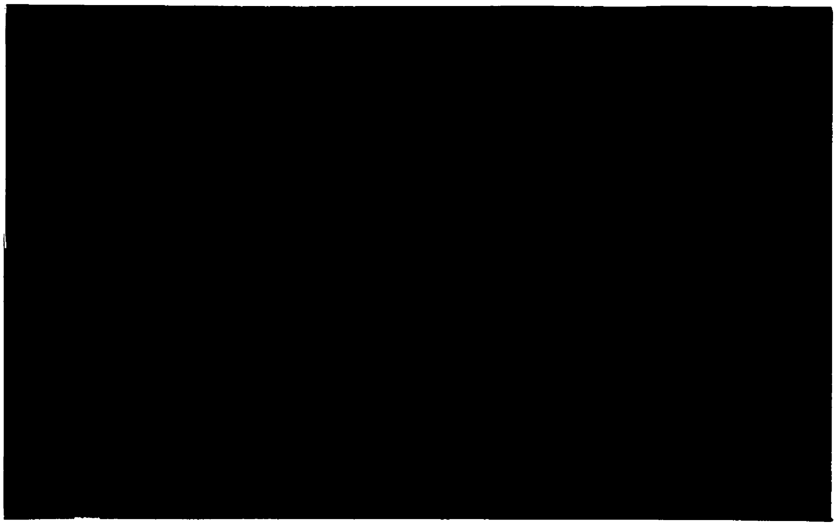
DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS
SYMONS HALL
UNIVERSITY OF MARYLAND
COLLEGE PARK 20742



DOUBLE COUNTING IN HEDONIC AND TRAVEL COST MODELS[1]

K. E. McConnell

Mailing address: Department of Agricultural and Resource Economics
University of Maryland
College Park, MD 20742
(301) 454-3809

Working Paper No. 89-30

September 1989

ABSTRACT

DOUBLE COUNTING IN HEDONIC AND TRAVEL COST MODELS

K. E. McConnell

When the value of access to a natural resource is measured by different methods, double counting sometimes occurs. This paper shows that when travel cost models and hedonic models are used to measure the value of access, the hedonic estimate includes the travel cost estimate. This result extends to damages from pollution. Both travel cost models and hedonic models can be exploited to measure the damages from pollution in a natural resource. But the hedonic model provides a broader measure which incorporates the travel cost estimate.

DOUBLE COUNTING IN HEDONIC AND TRAVEL COST MODELS[1]

Consider an imaginary situation in which an administrator of an environmental agency is responsible for reducing pollution in a lake. The pollution causes economic damage because the lake is less attractive for fishing and swimming. Evidence of the influence of pollution can be found through judicious sifting of the prices of houses near the lake and from reduced recreational use of the lake. The administrator of the environmental agency responsible for the lake wants to reduce the pollution in the lake but, cognizant of scarce resources, wants some evidence that the expensive investment in publicly owned treatment works will yield commensurate benefits. Consequently, she contracts with two economists for research on the benefits of environmental improvements. One will study the damages from the perspective of the housing market. The other will study the damages through the demand for recreation.

When the environmental administrator receives the estimates of damages from the two economists, should she add them together? This is the basic question explored in this paper. To what extent do travel cost models of the demand for recreation and hedonic models of housing measure the same damage when they are applied to pollution in the same resource? This analysis is similar in spirit but much simpler than that of Rosen (1979) and Roback. The latter work examines an equilibrium when the wage and the land price are affected by amenity levels.

The use of hedonic models to value access is not new. The spatial equilibrium model of a city can be viewed as a predecessor of the hedonic price model. In this model, formalized by Alonzo, the land rent gradient represents a tradeoff between commuting time and space. In the hedonic context, Nelson shows how the demand for commuting time and the price of housing interact to influence housing prices. Accessibility in some form, as a proxy for travel time, is a popular attribute of houses in hedonic models.

The issue addressed in this paper has relevance for litigation and for policy. It arises in cases of CERCLA (Superfund) concerned with the recovery of natural resource damages. Freeman describes a case where a hazardous substance released into New Bedford harbor apparently had an impact on the housing market near the harbor and on the recreational use of the harbor. This impact was studied with both a hedonic model and a travel cost model. Double counting is also a relevant issue when access to resources which are valued for their recreational returns are addressed in a hedonic framework.

The analysis of this paper applies generally to situations in which increasing access to one amenity directly reduces the access to another amenity. The Los Angeles housing market is a good case. Researchers have long realized that distance from the ocean is highly correlated with air pollution. Prices of houses near the ocean have lower travel costs for access to the ocean and lower levels of air pollution capitalized into them. The analysis of this paper could help provide an estimate of the economic value of air pollution in a place like Los Angeles. The hedonic model incorporates all of the influences of distance from the ocean, including air pollution, scenic amenities, and access to the beach. If a hedonic model could be coaxed into revealing a marginal benefit schedule for distance, it would stand for all the amenities which vary with distance. Doing a separate travel cost study for access to the beach would allow the recreational part of the amenities to be substantial from the total hedonic effect of distance.

The analysis in this paper assumes that the hedonic model can provide estimates of the parameters of preference functions. As is well known, this requires that the identification problem be solved. (See, for example, Bartik and Smith.) When preference parameters cannot be identified, the hedonic researcher will need to use the hedonic price function directly. While the use of this function typically overestimates benefits (see Kanemoto or Bartik), it is subject to the same forces which lead to double counting when the preference parameters are recovered.

THE BASIC MODEL WITHOUT POLLUTION

The polluted lake of concern to the environmental administrator is a summer vacation resort where the recreationists rent houses. Recreationists get utility which depends on how far they are from the water (distance, denoted s), the number of recreational trips (denoted z), and a Hicksian bundle (denoted x). Suppose that these vacation houses are identical except for the distance from the water. Recreationists themselves need not be identical. They may differ by income, tastes for environmental goods, and in other ways. In the standard hedonic model (Rosen, 1974; Bartik and Smith) the price of housing depends on the attributes of housing. In this simple model, the only attribute of the housing is distance from the water. Then the price of housing (P) depends only on distance and the hedonic price function is

$$P = h_0(s) \tag{1}$$

where $h_0'(s) < 0$. Housing costs decline with distance from the lake because travel costs go up. This naturally implies that the recreationists must pay for trips to the lake. Each trip costs \$c per mile times the number of miles s. The cost per mile c include both time and money elements. The money left over from income after house rental and recreational expenditures can be spent on the Hicksian bundle, which has its price normalized at one. The budget constraint is

$$y - x = h_0(s) + csz, \qquad [2]$$

reflecting the effect of distance on housing price and travel cost.

The individual's choice of housing can be viewed as a utility-maximizing one. When there are no non-recreational amenities from the water, the utility function is $u(x,z)$. The constrained utility function, when there is no pollution is

$$L(x,z,s,\lambda) = u(x,z) + \lambda(y - x - h_0(s) - csz) \qquad [3]$$

and the optimal conditions include

$$u_x = \lambda \qquad [4a]$$

$$u_z = \lambda cs \qquad [4b]$$

$$h_0'(s) = -cz. \qquad [4c]$$

Combining [4a] and [4b] gives the standard hedonic marginal expression:

$$-h_0'(s) = zu_z/su_x. \qquad [5]$$

The marginal cost of distance equals the marginal values of distance, which is travel cost times the optimal level of trips. This is analogous to the welfare result that the marginal value of a price change is the optimal quantity. In hedonic practice, $h_0'(s)$ is the marginal price or cost of distance.

Suppose that one wishes to measure the value of access (the loss from increased distance) when there is no pollution. If the economist doing the housing market study does not investigate the motives, but simply assumes that greater distance brings less utility, then he will want to use equilibrium conditions in the form of

$$\text{marginal price} = \frac{\text{marginal utility of attribute}}{\text{marginal utility of numeraire}} = \text{marginal bid for attribute.} \qquad [6]$$

When the attribute is distance from the lake, the value of access can be calculated as the area under the marginal bid function:

$$\text{loss in value of access} = \int_{s^0}^{s^*} \text{marginal bid } (s)ds \qquad [7]$$

where s^0 is the observed distance and s^* is the distance at which people no longer visit the lake. That is, s^* is the distance which, when multiplied by the cost per mile travelled, gives the choke price for the demand for recreational services. If the economist is lucky enough to observe this housing market operate over time, in an unpolluted state, he can solve the identification problem and estimate the parameters of the utility function which are embodied in the marginal bid function. Then he calculates [7] which is the loss in the value of access for the recreationist living in the house.

Typically in a hedonic study the researcher is ignorant of the structure of the utility function. In fact, this is one source of trouble in the identification problem. But in the case where distance increases travel cost, the researcher knows more of the structure of preferences. From [4c] we see that

$$-h_0'(s) = cz. \qquad [8]$$

Now apply the principle in [7] to the right-hand side of [8]. That is, integrating the right-hand side of [8] and changing variables from distance to the price of the recreation service yields

$$\int_{s^0}^{s^*} cz(s)ds = \int_{p^0}^{p^*} z(p)dp \qquad [9]$$

(where dp = cds is the change of variable). The function z(p) is the Marshallian demand that holds conditional on a household having chosen to live at distance s^0 from the lake. The right-hand side of [9] is simply the consumer surplus calculated from the travel cost model. Therefore, in a very simple model, when the motive for living close to the natural resource is the reduction in travel costs, the hedonic model and the travel cost model measure the same value of access. There is complete double counting for such individuals.

Two sets of questions arise in thinking about this result, as well as the results of the following sections.[2] First, it might be asked whether, since the household pays through travel costs and housing prices, one ought not to use both prices for the proper measure of the amenity. The second question is connected. If the household pays twice, how does it get any surplus? The questions are addressed in Figure 1. In panel A, the area a is the value of access for someone who lives at distance s^0. It is measured by the right hand side of equation [9]. The household pays b (which the landlord receives) and gets net surplus of c. When households are identical, the marginal bid function and the marginal hedonic price coincide, the landlord collects b, and c disappears. The benefits of access remain the same, but they are collected by the landlord. If the marginal price function were upward sloping, the landlord would collect more than the consumer gets for access alone. Hence, while the social value of access is given by expression [9], the distribution of this value depends on the functioning of the hedonic market. It is the social value of access (or improvements in water quality), not the consumer's surplus, which is relevant.

THE BASIC MODEL WITH AMENITIES FROM THE WATER BUT STILL NO POLLUTION

Consider the case where living near the water gives utility directly. For example, the wind off the water or the visual attractiveness of the water provides more direct utility the closer a house is to the lake. This is the "near the water" amenity. Hence, distance from the lake, s, is a plausible proxy of the amenity service flow associated with the housing service. The utility function becomes

$$u = u(x,z,s)$$

where $u_s < 0$ because s is distance from the lake. There is a new hedonic price function $h_1(s)$. Although a different function, it is still decreasing in distance because there are two reasons for wanting to be near the lake. The equilibrium conditions include

$$u_x = \lambda \qquad [10a]$$

$$u_z = \lambda cs \qquad [10b]$$

$$u_s = \lambda(cz + h_1'(s)). \qquad [10c]$$

These are the equilibrium conditions that prevail. A study of housing prices which examines only the conditions pertaining to housing choice will implicitly make inferences from the marginal housing price:

$$\begin{aligned} -h_1'(s) &= \text{marginal bid} \qquad [11] \\ &= cz - u_s/\lambda. \end{aligned}$$

The distance gradient now represents two reinforcing effects. Housing prices decrease with distance from the lake because the visual or aesthetic amenity from the lake is reduced (u_s) and because the costs of the recreational use of the lake increase. The term u_s/λ on the right-hand side of [11] is the standard for the hedonic model; the inclusion of the costs of recreation simply means that the hedonic model will capitalize the pecuniary effects of amenities. The right-hand side of [11] is the marginal bid function for the distance from the lake.

The housing value researcher recognizes that the marginal price equals the marginal bid, but does not know the decomposition evident in expression [11]. That is, he has not investigated motives and does not know that the marginal bid equals $cz - u_s/\lambda$. Calculating the area under the marginal bid function is equivalent to calculating the value of access. The value of access is simply the value of being at s^0 miles rather than s^* miles

$$\int_{s^0}^{s^*} \text{marginal bid } (s)ds = \int_{s^0}^{s^*} cz - \int_{s^0}^{s^*} u_s /\lambda \, ds \qquad [12]$$

$$= \int_{p^0}^{p^*} z(p)dp - \int_{s^0}^{s^*} u_s /\lambda \, ds$$

where the change in variables from distance to cost is the same as in equation [9]. Consequently, the area under the hedonic marginal bid function for distance measures two effects: the consumer's surplus from recreational use of the lake and the direct utility amenity from living near the lake.

So far the results show that to calculate the value of access, whether simply for recreational use or for both recreational and amenity use, only one economist is needed. A housing value study under conditions which allow identifications of preferences will include both the value of the resource for its recreational use and for its direct amenity. A recreational demand function is not needed. But what about when the lake is polluted?

The Model When Pollution Impairs Water Quality

A decline in water quality affects households in several ways. The direct amenities from being near the lake may be reduced, for example, by algal blooms. Severe pollution may bring odors, weakening the direct attraction from the lake. Water pollution also reduces the enjoyment of recreational activities.

Under the assumption that water quality only influences the well-being of recreationists or residents, the damage from the pollution can be calculated as the change in the value of access to the lake as a consequence of pollution. This assumption rules out non-use benefits such as existence value. It allows us to equate the damage from pollution to the change in the area under the marginal bid for distance to the lake.

When the water becomes polluted, preferences are shifted. Let the utility function become

$$u = u(x,z,s,\alpha)$$

where α is a variable measuring the extent of water pollution. One would expect that $u_\alpha < 0$ and $u_{s\alpha} > 0$. Increased water pollution mitigates the effects of distance from the lake on utility. If pollution becomes bad enough, u_s may become positive. A new hedonic price function $h_2(s)$ emerges. As in the other cases, the price of housing declines with distance, although the effect is attenuated because pollution reduces the demand for recreation and impairs the "near the water" amenity. Equilibrium conditions include

$$u_x(\alpha) = \lambda \qquad [13a]$$

$$u_z(\alpha) = \lambda cs \qquad [13b]$$

$$u_s(\alpha) = \lambda(cx(\alpha) + h_2'(s)) \qquad [13c]$$

where $h_2'(s)$ is the new hedonic gradient and α is introduced as a mnemonic in the first-order conditions to indicate utility's dependence on pollution. Because distance from the lake is by itself a disamenity, one cannot learn about damages from pollution by observing the housing equilibrium at one point in time. In a setting where pollution simply reduces the attractiveness of the resource, the housing gradient becomes less steep but is not otherwise different from a housing gradient without pollution. Evidence of the impact of pollution on housing values can be derived by showing that the hedonic gradient becomes less steep as pollution increases.

To infer damages from pollution, calculate the change in the value of access as a consequence of pollution. From [13c], the marginal value of access in equilibrium is

$$-h_2'(s) = cz - u_s(\alpha)/\lambda$$

Analogous to [12], the value of access is the area under the marginal bid function:

$$\int_{s^0}^{s^*} \text{marginal bid } (s)ds = \int_{p^0}^{p^*} z(\alpha,p)dp - \int_{s^0}^{s^*} \frac{u_s(\alpha)}{\lambda}\, ds$$

Both the recreational demand function z and the marginal (dis-) utility from distance depend on water pollution. For a household living s^0 miles from the lake, the damage from water pollution is

change in area under marginal bid function =

$$\int_{p^0}^{p^*} [z(\alpha^1,p) - z(\alpha^0,p)]dp - \left(\int_{s^0}^{s^*} \frac{u_s(\alpha^1)}{\lambda} ds - \int_{s^0}^{s^*} \frac{u_s(\alpha^0)}{\lambda} ds \right) \qquad [14]$$

where α^0 is the original level of pollution and α^1 is the new higher level. This measure is the sum of the change in the direct utility or aesthetic effect of the "near the lake" amenity and the change in the value of access for recreational purposes. Expression [14] is the cost of a decline in water quality from α^0 to α^1 as calculated by the housing value economist. It assumes that households do not adjust to changes in water quality. Without adjustment, the benefit from improved water quality and less than they would be with adjustment. How does it compare with the damage calculated by the recreational economist? The economist working on the recreational demand for the lake would calculate

$$\text{recreational damage} = \int_{p^0}^{p^*} (z(\alpha^1,p) - z(\alpha^0,p))dp$$

for an individual living $s^0 = p^0/c$ miles from the lake. Consequently, the hedonic model is more general. It calculates not only the direct amenity loss from water pollution of the lake, but also the loss in value of the recreational opportunity.

CONCLUSION

The environmental agency administrator is now ready to receive the two reports from the consultants. The housing value study presents one estimate of pollution damage. The recreational demand study presents another. But the administrator knows that total damage from water pollution is not the sum of damages from the two studies. The studies may be used in support of each other. For example, without extenuating circumstances, the recreational damages for a renter living within the zone of influence of the lake should be less than the damages from the housing study.

In a number of ways, applied studies differ from the models adopted in this paper. First, hedonic models frequently are applied to the sales price of the house, rather than rental values. This means the expected future service flows for the "near the water" amenity and for recreation are capitalized into the housing price. Recreational demand studies are typically based on surveys of actual behavior. It is thus not too great a leap to argue that the present discounted value of pollution damage from a hedonic model is an *ex ante* concept, containing valuation of expectations of future service flows. The recreational study is more closely an *ex post* concept. Second, in practice one rarely has the ability to estimate the parameters of the marginal bid function. Instead it is commonplace to use the predicted changes in hedonic prices as a measure of damages (see the papers by Bartik and Kanemoto for the nature of approximations inherent in this approach). Yet even when the change in the hedonic price is used, in the circumstances of this paper it is partly induced by the value of recreational access.

DBLCOUNT.WP/ic/10-6-89

REFERENCES

Bartik, T. J. 1988. "Measuring the Benefits of Amenity Improvements in Hedonic Price Models." Land Economics 64:172-183.

Bartik, T. J. and V. K. Smith. 1987. "Urban Amenities and Public Policy." In Handbook of Regional and Urban Economics, Vol. II, ed. E. S. Mills. Elsevier Science Publishers, 1207-1254.

Freeman, A. Myrick III. 1987. "Assessing Damages to Marine Resources: PCBs in the New Bedford Harbor." Paper presented at the 1987 American Economic Association meetings.

Kanemoto, Y. 1988. "Hedonic Prices and the Benefits of Public Projects." Econometrica 56:981-989.

Roback, J. 1982. "Wages, Rents, and the Quality of Life." Journal of Political Economy 90:1257-1278.

Rosen, S. 1874. "Hedonic Prices and Implicit Markets: Product Differentiation in Price Competition." Journal of Political Economy 82:34-55.

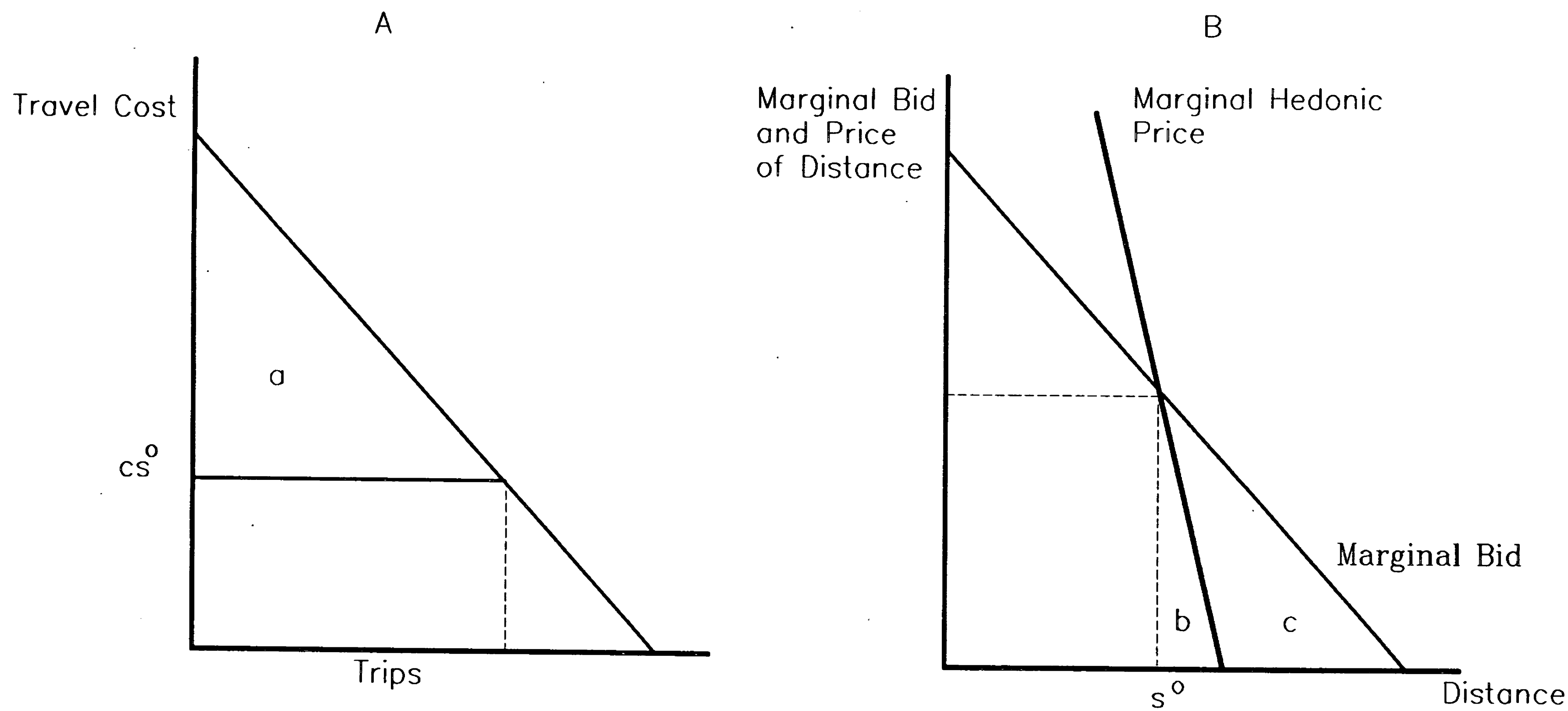
Rosen, S. 1979. "Wage-based Indexes of Urban Quality of Life." In Current Issues in Urban Economics, eds. P. Mieszkowski and M. Straszheim. Baltimore: Johns Hopkins Press.

FOOTNOTES

[1] Contribution xxxx, Scientific Article No. x-xxxx of the Maryland Agricultural Experiment Station. This research was supported in part by the Environmental Protection Agency Cooperative Agreement CR-811043-01-0 with the University of Maryland, although publication of this paper does not imply approval or review by EPA. I thank Tim Bartik and George Parsons for insightful comments on this paper.

[2] These diagrams were suggested by Tim Bartik. George Parsons also suggested a similar argument.

Figure 1


A
Travel Cost
a
cs°
Trips
B
Marginal Bid
and Price
of Distance
Marginal Hedonic
Price
Marginal Bid
b
c
s°
Distance