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Recreation at open space and residential development patterns

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Abstract

The presence of open space on an economic landscape influences the area, density, and prices of residential development. We show that the kind of influence that open space has on urban form matters for planning and recreation goals. In our spatial city model residents prefer to live close to open space for the benefits of (1) recreation and (2) ambient amenities. Our findings suggest that the type of benefits offered by open space matter for the optimal proximity of open spaces to each other and the city center. We show that policies adjusting recreation benefits and costs are able to influence the urban form to achieve planning and recreation goals. Open space benefits influence the location pattern of income groups, and we show that high income groups locate away from open space if increases in income make housing demand rise faster than recreation demand.

1 Introduction

Public open space offers many benefits to the households of cities including recreational opportunities, environmental and ecosystem benefits, and scenery. Evidence that the benefits of open space are substantial is clear from the support the public has given to ballot measures to conserve, create, and rehabilitate open space. In Spring 2005, voters in 51 communities approved over $1 billion in land conservation funds bringing the full tally of funds since 2000 to $18.1 billion [20].

A substantial proportion of the benefits from public open space are from recreation since most people in the United States engage in basic outdoor recreation. Eighty-two percent of people do walking for pleasure, 73% have family gatherings, 56% go picnicking, and 53% go sightseeing. Further, participation in these activities is growing. From 1995 to 2000, 40 million more people began walking for pleasure, family gathering grew by 36 million, picnicking grew by 20 million, and sightseeing grew by 24 million [15].

The influence of amenities, such as open space, on urban spatial structure is a long-standing area of research ([6,16,27,29]). Since households are drawn to open space, housing prices and development densities around the open space rise. The literature has the basic story correct, but a fuller understanding of the influence of open space on urban spatial structure requires a closer examination of the benefits that open space offers.

This paper examines how the different types of benefits of open space, in particular recreation, influence urban spatial structure. The principal types of benefits open space offers are recreation and ambient amenities. The recreation benefits of open space are available to households at any location in the city, but a household incurs a low travel cost for the visit to the open space. The ambient amenity benefits are only available to households at locations a short distance away from the open space, but a household incurs no costs to receive the ambient amenities. Common types of ambient amenities are scenery and ecosystem benefits such as the removal of pollutants from the air and water by vegetation or soils.

Different kinds of open space offer different levels of recreation and ambient amenities. Open spaces such as rivers, lakes and oceans offer high levels ambient amenities through scenery and the cleaning of the air by the water while open spaces such as hills and grasslands offer predominantly recreation benefits.

A key reason city planners create public open space is to improve a city's quality of life. Since migration between cities is often not possible in the short-run and difficult in the long-run, the amount and spatial arrangement of open space has a palpable influence on the welfare of households in a city. The spatial city model developed to reflect these beliefs is the closed city model in the tradition of Alonso-Muth-Mills. Households choose among residential sites differentiated by the price of housing, commuting cost, recreation cost, and ambient amenities. Developers choose the density of housing from the prevailing price of housing at a location. The city's household welfare or equilibrium utility adjusts in response to changes in the framework of the city. The spatial market equilibrium is examined through simulations.

Public open space exists in cities either because the terrain prohibits development or a government agency has purchased the land for conservation purposes. We show that the type of benefits offered by open space influence the optimal spatial arrangement of open space on the landscape. For open space offering high levels of ambient amenities, the highest level of household welfare and lowest developed area results if the open spaces are concentrated together near the city center. For open spaces offering predominantly recreation benefits, the highest level of household welfare results if the open spaces are spatially spread apart from each other to reduce the total recreation travel costs of households. These findings are of interest to city planners deliberating where to create additional open space in the context of existing open space.

Public policies adjusting recreation costs and benefits are examined to more thoroughly explore how recreation influences urban form. The public policies we examine are a prohibition on recreation, adjustment of user fees, per mile cost of travel for recreation, and site quality of the open space. Since the effects of each policy on the urban spatial structure differ in degree and kind, the policies represent a palette of tools for planners trying to achieve multiple objectives. The benefits of open space influence the spatial distribution of income groups, and counter to the standard conclusion ([1,28]) the high income group is not always attracted to the open space if housing demand rises faster than recreation demand. Also, the spatial arrangement of open space is shown to influence the social tension between the income groups.

Many prior studies use similar spatial city models for examining the influence of open space on urban spatial structure ([11,27,28,29]). Yang and Fujita [29], and also Fujita et. al [6], show that open space, not only the CBD, influences the land price gradient of a city. Yang [28], and also Lee and Fujita [11], examine the effects of the size of a central park and configuration of a greenbelt, respectively, on urban spatial structure. Wu and Plantinga [27] enrich the spatial city model by referencing the landscape with two-dimensional spatial coordinates. Their new framework for the spatial city model allows them to examine in a richer fashion the issues of the prior studies.

The spatial city model of our study adopts the richer framework developed by Wu and Plantinga [27]. The main difference of our study from the others is that we examine more exhaustively the types of benefits that open space offers. The representation of amenities in the spatial city model of Wu and Plantinga [27] is what we call ambient amenities in our study. The different types of benefits of open space in our model allows us to examine the *kind of influence* open space has on urban spatial structure.

Brueckner et al. [1], and also Wu and Plantinga [27], show that richer households are attracted to open space. Brueckner et. al [1] argue that amenity levels may be high enough in European cities to attract the richer households to the city center. Our study finds that open space does not attract richer households if rises in income increase the demand for housing much faster than the demand for recreation.

2 Recreation at open space in a closed city model

In the Alonso-Muth-Mills tradition, the urban area containing the residential developments of interest has a single central business district (CBD) which households commute to for employment. The households have identical incomes and preferences, and the commuting cost depends on the distance between the residence and the CBD. Land developers utilize identical constant returns to scale technology for residential development. The market for residential development is perfectly competitive, and the development profits are zero.

Households choose a residential location from preferences defined over home size, recreation, the level of ambient amenities, and a non-housing (numeraire) good with the commuting cost represented in the budget constraint. Land developers choose the location, home size, and density of development to maximize profits. The interaction of the household preferences for housing and the profit motives of the land developers results in the spatial market equilibrium of the city.

Since a city's quality of life is often of interest to planners and inter-city migration is usually costly, our study examines the closed city model. The closed city model assumes that the population of the households is fixed and the utility of households fluctuate in response to changes in the framework of the city.

2.1 The household location decision

The landscape of the model is represented by the Cartesian plane $(u, v) \in \mathbf{R}^2$, and the CBD is represented by a single point located at the origin (0,0). The u-axis is the west-east direction in miles, and the v-axis is the south-north direction in miles. All of the landscape other than the origin is available for residential development.

The population of households has identical income and preferences. A household located at the residential site (u, v) has a commuting distance in miles to the CBD of $x(u, v) = \sqrt{u^2 + v^2}$. The distance of most commutes is longer than the shortest distance between a residential site and the CBD. However, the common use of highways in urban areas for commuting makes the assumption not a bad approximation.

Residential sites are differentiated by their proximity to the amenities. Heterogeneity in the ambient level of amenities is represented by the distribution function $a((u, v), rd)$ defined over the landscape. The proximity and physical size, represented by the radius rd, of the circular amenities near the residential site (u, v) influences the magnitude of $a((u, v), rd)$. The magnitude of $a((u, v), rd)$ asymptotically approaches the base value of 1 for residential sites sufficiently far away from all of the amenities. Examples of ambient amenities at a residential site include scenery and ecosystem benefits.

Heterogeneity in the cost of a recreation trip over the landscape is represented in the household budget constraint by $k(u, v)$. The proximity of the amenity closest to the residential site (u, v) influences the magnitude of $k(u, v)$ since trips require travel costs. Since each amenity is identical by assumption, the proximity of amenities other than the amenity closest to the residential site (u, v) does not influence the magnitude of $k(u, v)$.

The magnitude of $k(u, v)$ does not rise proportionally with distance from an amenity since the city streets usually traversed to reach an amenity often contain additional barriers to travel. For instance, a household twice the distance away from an amenity incurs more than twice the travel cost for a recreation trip. Households at residential sites directly adjacent to an amenity have zero travel cost for a recreation trip, but there is an admission fee, af, for access to the amenity.

Each household takes the price per square foot of residential space, $p(u,v)$, the commuting distance in miles, $x(u,v)$, the ambient level of amenities, $a(u,v)$, and the cost of a recreation trip, $k(u,v)$, as given. Accordingly, by selecting the residential site (u,v), the household is simultaneously choosing a housing price, a commuting distance, an ambient level of amenities, and a cost of a recreation trip.

2.1.1 Positive number of recreation trips

Each household chooses among residential space q, recreation trips T, residential site (u,v), and a numeraire "all other consumption" good g to maximize utility $U(q,T,g,a((u,v),rd))$. The budget constraint of the household is $p(u,v)q + k(u,v)T + g + tx(u,v) = y$, where y is the gross household income, and t is the round-trip commuting cost per mile. The utility function specification chosen is Stone-Geary since the demand for recreation trips is believed to have a finite choke price.

$$U(q,T,g,a((u,v),rd)) = a((u,v),rd)^{\gamma} q^{\alpha} (T+1)^{\beta} g^{\tau}, \qquad (1)$$
$$\text{where } \alpha, \beta, \tau \text{ and } \gamma > 0.$$

The first order conditions for the utility maximization problem specify the optimal choices of residential space, recreation trips, and the numeraire good for the locations where households take a positive number of recreation trips:

$$q^*(u,v) = \frac{\alpha(y - tx(u,v) + k(u,v))}{(\alpha+\beta+\tau)p(u,v)} \qquad (2)$$

$$T^*(u,v) = \frac{\beta(y - tx(u,v) + k(u,v))}{(\alpha+\beta+\tau)k(u,v)} - 1 \qquad (3)$$

$$g^*(u,v) = \frac{\tau(y - tx(u,v) + k(u,v))}{(\alpha+\beta+\tau)} \qquad (4)$$

Competition for housing bids up the prices of housing in desirable locations. In the closed city, utility adjusts to changes in the framework of the city. However, in equilibrium, household utility $\overline{V}$ is identical across households. Households far away from the CBD have longer commutes but pay less for housing than households closer to the CBD.

Substituting (2)-(4) into the utility function (1) and setting utility equal to $\overline{V}$ yields the bid price of housing for the locations where households take a positive number of recreation trips:

$$p^*(u,v) = \left[\frac{a((u,v),rd)^\gamma \alpha^\alpha \tau^\tau}{\overline{V}} \left(\frac{y - tx(u,v) + k(u,v)}{\alpha+\beta+\tau}\right)^{\alpha+\beta+\tau} \left(\frac{\beta}{k(u,v)}\right)^\beta\right]^{\frac{1}{\alpha}} \tag{5}$$

The bid price equation (5) reveals the influence of amenities on the household's maximum willingness to pay for housing at location (u, v). The heterogeneity in the ambient level of amenities across the landscape, represented by $a((u,v),rd)^\gamma$, directly influences the bid price of housing. If the ambient level of amenities is high enough, households may be willing to pay more for housing close to an amenity than housing close to the CBD.

The proportion of household income spent after commuting costs on recreation, β, and the cost per trip of recreation, $k(u,v)$, operate together to influence the bid price of housing. If there is spatial variation in $k(u,v)$, then the cost per trip of recreation produces spatial variation in the bid price of housing. If there is no spatial variation in the cost per trip, $k(u,v) = k$, then all households benefit(lose) equally from a fall(rise) in the cost per trip of recreation, and no spatial variation is produced from the recreation costs on the bid price of housing.

The magnitude of the proportion of household spending on recreation, i.e β, influences the sensitivity of housing prices to spatial variation in the cost per trip of recreation. For instance, if recreation is a large proportion of household spending, i.e. high β, then even slight spatial variation in the cost per trip of recreation produces significant spatial variation in the bid price of housing. Naturally, changes in recreation costs have a stronger influence on housing prices if recreation is a large component of household spending. The issues surrounding the influence of amenities on housing prices are analyzed in more detail later in the chapter.

For households at a distance far enough away from every amenity, zero recreation trips to any amenity is optimal. As the distance from an amenity increases, the travel cost component of the cost per trip rises until the choke price of recreation trips is reached. Setting (3) equal to zero and rearranging yields the choke price of recreation trips, $\hat{k}(u,v) = \frac{\beta(y-tx(u,v))}{\alpha+\tau}$. The proportion of household spending on recreation defines the choke price. A higher proportion of household spending on recreation implies that households at greater distances from an amenity will still take recreation trips.

The area beneath the inverse demand for recreation trips between the cost of a recreation trip for a household and the choke price of recreation trips is the net benefit of recreation for that household. Solving for the net benefits of recreation yields, $NB(u,v) = \frac{\beta(y-tx(u,v))}{\alpha+\beta+\tau}(\ln \hat{k}(u,v) - \ln k(u,v)) - \frac{\alpha+\tau}{\alpha+\beta+\tau}(\hat{k}(u,v) - k(u,v))$. The net benefits from recreation depends on the gap between the choke price of recreation trips and the cost of a recreation trip for a household. Households nearby open space receive greater net benefits from recreation. Also, the income less commuting costs of households influences the net benefits from recreation. The income less commuting costs shifts the demand for recreation trips.

2.1.2 Zero recreation trips

If the cost per trip exceeds $\hat{k}(u,v)$, then no recreation trips are taken by the household, and the utility maximization problem of the household changes. Now, the household maximizes $U(q,g,a((u,v),rd)) = a((u,v),rd)^{\gamma}q^{\alpha}g^{\tau}$ subject to $p(u,v)q + g + tx(u,v) = y$.

From the first order conditions of the new utility maximization problem and from setting utility equal to $\overline{V}$, the bid price of housing for the locations where households take zero recreation trips is:

$$p^*(u,v) = \left[\frac{a((u,v),rd)^{\gamma}\alpha^{\alpha}\tau^{\tau}}{\overline{V}}\left(\frac{y - tx(u,v)}{\alpha+\tau}\right)^{\alpha+\tau}\right]^{\frac{1}{\alpha}}. \qquad (6)$$

The cost of a recreation trip $k(u,v)$ and the preference for recreation β no longer influence the bid price of housing equation (6). The ambient level of amenities potentially still influences the bid price of housing although the influence is likely non-existent since ambient benefits of amenities dissipate faster than recreation benefits with distance from an amenity.

2.2 The residential development decision

The supply side of residential development follows the study of Wu and Plantinga [27]. Residential developers choose the location (u,v) and density

s (total residential space per acre) of development to maximize profits per acre $\pi((u,v),s)$. The profit per acre $\pi((u,v),s) = p(u,v)s - c((u,v),s)$, where $p(u,v)$ is the price of residential space and $c((u,v),s) = r(u,v) + c(s)$ are total costs that include the price per acre of land $r(u,v)$ and the building costs $c(s)$. The building costs $c(s) = c_0 + s^\delta$ include laying the foundation c_0 and the construction s^δ, with $\delta > 1$.

The first order condition for profit maximization implies that

$$s^*(u,v) = [p^{**}(u,v)/\delta]^{1/\delta}. \tag{7}$$

Equation (7) shows that the density of housing at (u,v) increases with the price of residential space at (u,v). $p^{**}(u,v)$ is the minimum selling price for residential space at (u,v). Combining together equation (7) with the knowledge that profits must be zero in competitive market equilibrium obtains the developer's bid price for land

$$r^*(u,v) = \left[\frac{(\delta-1)^{\frac{\delta-1}{\delta}}}{\delta} p^{**}(u,v)\right]^{\frac{\delta}{\delta-1}} - c_0. \tag{8}$$

Equation (8) shows that the price of land at (u,v) increases with the price of residential space at (u,v).

2.3 Conditions of spatial market equilibrium

Five conditions combining the household location decision and residential development decision characterize the spatial market equilibrium. The first equilibrium condition is that housing prices are bid up until no household has the incentive to move. This condition is satisfied when housing prices are represented by (5) since the household's bid function is the maximum willingness to pay for housing.

The second equilibrium condition is that at each location the price households are willing to pay for housing equals the price developers are willing to accept for housing. This second condition is satisfied when $p^*(u,v) = p^{**}(u,v)$. The third equilibrium condition is that land price are bid up until the profits are zero everywhere and developers are indifferent to the location of development. The third condition is satisfied when land prices are represented by (8) since the developer's bid function is the maximum willing to pay for land.

The fourth equilibrium condition is that all households are accommodated such that the total supply of housing equals the total demand of housing. The household density $n(u,v)$ (households per acre) is the development density (residential space per acre) divided by the housing demand per household (residential space per household). Since land is developed if the developer's bid price for land exceeds the agricultural rent r_{ag}, the developed area is the set $\{(u,v)|r^*(u,v) \geq r_{ag}\}$.

$$\int\int_{r^*(u,v)>r_{ag}} 640\frac{s^*(u,v)}{q^*(u,v)}\, du\, dv = N, \tag{9}$$

determines the equilibrium utility of the households $\overline{V}$ in the closed city model, and N in the open city model. The 640 is the conversion factor from acres to square miles since household density is per acre but u and v are measured in miles.

The fifth equilibrium condition is that the city boundary is the set of locations where the land price equals the agricultural rent, $\{(u,v)|r^*(u,v) = r_{ag}\}$.

The mechanisms of the model are illustrated here briefly through comparative statics. First, suppose an open city model since the comparative statics are more straightforward than for the closed city model. A rise in income, a fall in commuting costs, or a fall in recreation costs causes in-migration and increases in housing and land prices throughout the city. To convince yourself, note from (5) and (8) that $\partial p^*/\partial y > 0$, $\partial p^*/\partial t < 0$, $\partial r^*/\partial y > 0$, and $\partial r^*/\partial t < 0$ for any (u,v), and $\partial p^*/\partial k < 0$ and $\partial r^*/\partial k < 0$ for all (u,v) where there is a positive number of recreation trips. Wherever housing prices increase, (2) and (7) illustrate that the demand for residential space q falls and the density of development s rises. The rise in land prices increases the developed area defined by $\{(u,v)|r^*(u,v) \geq r_{ag}\}$. Bringing these results together indicates that the left-hand side of (9) increases, and the number of households N must rise to restore equilibrium.

Now, suppose a closed city model. Since the level of utility readjusts in response to changes in the parameters, the mechanics of the closed city version of the model are a good deal more complex. The comparative statics were first fully laid out by Wheaton [23]. A rise in income, a fall in commuting costs, or a fall in the recreation costs (for the special case of no spatial variation in the recreation costs, i.e. $k(u,v) = k$) cause the utility level to rise, the developed area to increase, and the housing and land price gradients to flatten.

Following the logic from the open city model derivation, to roughly illustrate the derivation by Wheaton [23], a fall in recreation costs makes housing and land prices rise, the demand for residential space fall, the density of development rise, and the developed area expand. The difference from the open city model is that the number of households is fixed, and the utility level imbedded within the left-hand side of (9) adjusts to restore equilibrium.

A rise of the utility level simultaneously increases the demand for residential space and lowers the density of development in order to equate the left-hand side of (9) to N. Note from (5) that the rise in the utility level causes housing and land prices to fall faster near the city center than at the city boundary since the numerator of (5) is larger near the city center. The result is that the housing and land price gradients flatten. The fall in land prices at the city boundary in the utility adjustment process suggests that the developed area expands less than in open city model.

The comparative statics for a fall in the recreation costs, where there is spatial variation in the recreation costs, for the closed city case are mathematically intractable. However, intuition suggests that the areas of the city where recreation costs are important are likely to exhibit a greater expansion in the developed area and flatter housing and land price gradients. The areas of the city where recreation costs have no importance are likely to exhibit a contraction in developed area and a steepening of housing and land price gradients. The numerical simulations later in this chapter better illustrate the influence of recreation costs on the urban spatial structure.

3 Recreation, ambient amenities and property values in a closed city

Simulations of our spatial city model enable an examination of the effect of the different types of benefits of open space on urban spatial structure. Households receive benefits from the open space in the form of recreation and ambient amenities. A government agency is able to create open space on a landscape with existing open space. Also, the government agency is able to change the quality of the open space in a way that the benefits of recreation change, but the benefits of the ambient amenities remain the same.

Simulation examine two types of spatial arrangements of open space. Open spaces are created at different proximities to each other to investigate the importance of the spatial concentration of open space. Also, open spaces are created at different proximities from the CBD to investigate the connection between open space benefits and commuting costs. These simulations are done with and without the presence of ambient amenities to examine how much each type of open space benefit influences the urban spatial structure and recreation behavior of households. Next, we examine public polices influencing recreation costs and benefits to understand how planners might use the benefits of open space to influence their city. Finally, we investigate how the different open space benefits influence the spatial distribution of income groups.

Table 1 lists the parameter values of the simulations. The Stone-Geary specification for utility is appropriate for representation of preferences across broad categories such as housing, food, and entertainment. Parameter values for the Stone-Geary utility are chosen based upon the household budget shares of the most recent consumer expenditure survey [2]. Since households spend about 30-35% of income on housing and 20-25% of income on commuting, the share of income after commuting costs spent on housing is around 40%, i.e. $\alpha = 0.4$.

Since households spend about 5% of income on entertainment, the parameter value of $\beta = 0.05$ is roughly correct since not all entertainment expenditures are for recreation. The intra-city travel cost per mile for recreation trips, $\theta = 2$, is consistent with the annual commuting cost per mile, $t = 1000$. The minor discrepancy between the travel costs is because travel for commuting is often along freeways while intra-city travel is often along streets with traffic lights. The parameter value units are based upon the assumption that each point (u, v) on the landscape is an acre of land.

Since the simulations are of the closed city model, the number of households, N, is exogenous. Since $N = 2000$, our spatial city model is representative of a small city.

A city with no open space is circular and all the land within the city boundary is developed. There are no recreation opportunities for households, and the ambient amenities are uniformly distributed across the city and normalized to one (i.e., $a(u, v) = 1$). The city is circular since land prices depend only on the distance to the CBD. In panel (a) of Figure 1, the city with no public open space is shown. For all the figures, the contours represent the level of the land prices. Recall that housing and land prices are directly related to each other through (8). The darkest contour indicates the region of the highest land prices while the lighter contours indicate progressively lower land prices. The white contour represents undeveloped agricultural land.

In the spatial equilibria of cities with open space, the city no longer has a circular shape since land prices depend on the distance to the open space as well as the CBD. Not all the land within the city boundary is developed since some land is open space surrounded by development.

Suppose there is a circular amount of public open space located at $(ac1, ac2)$. The cost of a recreation trip has the form $k(u,v) = \theta z^{\psi} + oc$, where $z = \left(\left(u - ac1 + \frac{(u-ac1)*rd}{\sqrt{(u-ac1)^2+(v-ac2)^2}} \right)^2 + \left(v - ac2 + \frac{(v-ac2)*rd}{\sqrt{(u-ac1)^2+(v-ac2)^2}} \right)^2 \right)^{0.5}$ is the distance between the household location (u, v) and the closest edge of the nearest circular open space; θ is the cost of a recreation trip for a household living one mile away from the open space; ψ is the rate at which intra-city travel costs increase with distance, and oc is the on-site cost of a trip that includes user fees and the opportunity cost of time at the open space.

Since the cost of a recreation trip increases the further a household is from the open space, the attractiveness of the location, and thus the housing price at that location, declines with distance from the open space. Note this by substituting, $k(u,v) = \theta z^{\psi} + oc$, into the household's bid price (5). Since each circular open space is assumed identical, a household takes all its recreation trips to the closest open space.

The ambient amenity function is assumed to have the form $a(u,v) = 1 + a_d(e^{\phi rd + \lambda(0.1-rd)(1+(rd-0.1))^2} - 1)(e^{-\eta \mathbf{z}} \cdot \mathbf{1})$, where $\mathbf{z}$ is a vector of distances between the household location (u, v) and the closest edge of each circular open space in the city, a_d is the level of ambient amenities provided to a household located at the edge of an open space, ϕ and λ determine how much the size of each open space influences the ambient amenities, and η determines the rate at which ambient amenities declines the further a household is from each open space.

Unlike the benefits households receive from recreation, where only the closest public open space matters, every open space potentially has an influence on the ambient amenities at location (u, v). However, only open space close to (u, v) increases the level of ambient amenities since $a(u, v)$ falls off very quickly with distance from open space to the normalized value of one. Since ambient amenities declines the further a home is from the open space, here is another reason that the attractiveness of a location, and thus the housing price at that location, declines with distance from open space. Note this by substituting $a(u,v) = 1 + a_d(e^{\phi rd + \lambda(0.1-rd)(1+(rd-0.1))^2} - 1)(e^{-\eta \mathbf{z}} \cdot \mathbf{1})$ into the household's bid price (5).

3.1 Open space proximity to each other

3.1.1 Ambient amenities present

Panels (b)-(d) of Fig. 1 illustrate how the proximity of open spaces to each other influence the land price gradient of a city with ambient amenities. Panel (b) shows two public open spaces opposite each other across the CBD at $(0,1)$ and $(0,-1)$. In panels (c)-(d), the open space initially at $(0,1)$ is brought clockwise around the city towards the open space at $(0,-1)$. The open spaces are kept at the same distance from the CBD in panels (b)-(d) to investigate only the influence of open space proximity to each other.

The closer the open spaces are to each other the greater the proportion of the city area having the darkest shading for land prices. The reason for this is that both open spaces influence the ambient amenities at a location. Since locations between the open spaces receive two doses of ambient amenities, those locations are especially attractive, and land prices rise even more there.

Another observation from Fig. 1 is that the closer the open spaces are the more that the city develops away from the CBD. The commuting costs of the households increase if households locate further from the CBD. Higher commuting costs reduce the income available for all other goods.

Comparing a city with no open space in panel (a) to panels (b)-(d), the presence of open space steepens the land price gradient. In particular, the ambient amenities make the locations close to the open spaces very attractive, and the land prices there are elevated significantly above the land price at the city boundary, r_{ag}. Since the locations between the open spaces become more attractive the closer the open spaces are to each other, the land price gradient is the steepest in panels (c)-(d).

Table 2 lists the equilibrium features of urban spatial structure of the cities in Fig. 1. A city with open space has a higher equilibrium utility level, a smaller developed area, and higher housing density and total land rents. Since open space increases utility through recreation trips and ambient amenities, equilibrium utility, or household welfare, is higher in the cities with open space. The rise in housing prices from the open space stimulates greater housing density. Since the number of households is fixed in the closed city model, the greater housing density reduces the developed area of the cities. In contrast, in the open city model, the in-migration caused by the open space may increase the developed area.

Perhaps the most important feature of the spatial market equilibrium for

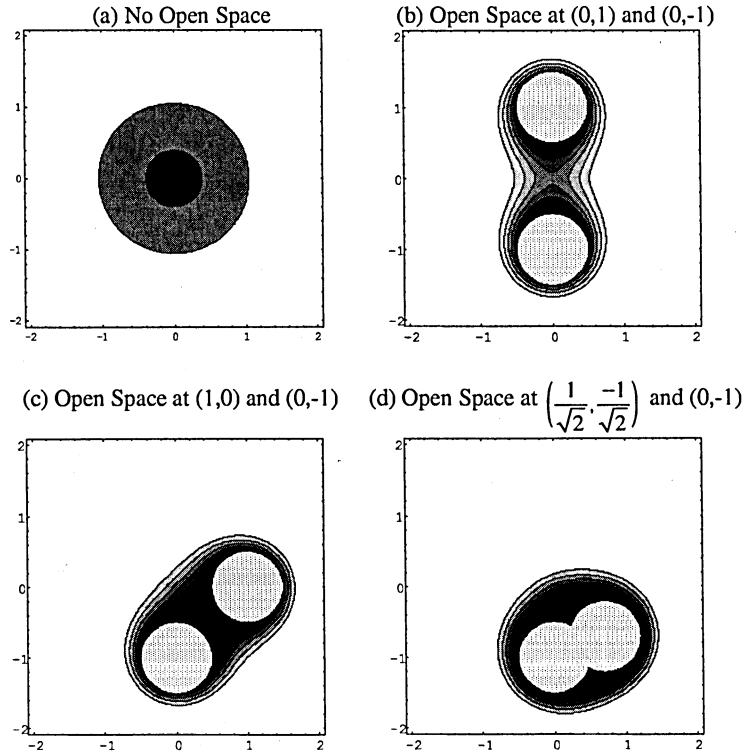

Figure 1: Open spaces at different proximities to each other for a closed city model with ambient amenities. (a) No open space; (b) open space at $(0,1)$ and $(0,-1)$; (c) open space at $(1,0)$ and $(0,-1)$; (d) open space at $(\frac{1}{\sqrt{2}}, \frac{-1}{\sqrt{2}})$ and $(0,-1)$.

a planner is the equilibrium utility since a planner wants to know the effect of the creation of open space on household welfare. The equilibrium utility rises then falls as the open spaces become closer to each other. The equilibrium utility rises initially because of the double dose of ambient amenities. However, as the open spaces become very close, the area between the open spaces disappears, and the developed area shifts away from the CBD resulting in greater commuting costs.

As the open spaces become close, the land near the open spaces becomes more attractive. Whenever a small area is very attractive, high density development occurs in that area, and the developed area of the city falls. In a city with no open space, the CBD is the most attractive location. For cities with open space, the land around the open space is the most attractive region. One reason is the choice of a high value for the parameter γ. Another reason is that the level of the ambient amenities declines quickly with distance from the open space. Since the high level of ambient amenities is only available in a small region around the open space, the land near the open space is especially attractive relative to the other locations on the landscape.

If planners want to raise money for the creation of open space by taxes on land, the open space should be created in close proximity to generate the highest total land rents. However, the open spaces should not be created too close because the land between the open spaces receiving double doses of ambient amenities would be lost. Since equilibrium utility also rises with the closer proximity of the open spaces, the planner is simultaneously optimizing household welfare.

Table 3 lists the equilibrium features of recreation at the open space in Fig. 1. As the public open spaces become closer, the total net benefits of recreation and the ratio of recreation trips to travel costs initially rise then drop. The ratio of recreation trips to travel costs initially rises since households crowd nearer to the open spaces. When the open spaces are closest to each other, households still crowd close to open spaces, but the recreation trips fall since the higher commuting costs shift down recreation demand. Also, the total travel costs of recreation rise since the perimeter of the open space falls since the open spaces overlap.

While the total net benefits of recreation are partially influenced by the ratio of recreation trips to travel costs (i.e. a direct relationship exists between the two), the income less commuting costs of the households is the most substantial influence. The city where the open spaces are the closest to each other corresponds to the lowest total net benefits since commuting costs are the highest due to the shift of the developed area away from the CBD.

3.1.2 Ambient amenities absent

Panels (b)-(d) of Fig. 2 illustrate how the proximity of open spaces to each other influence the land price gradient if open spaces offer only recreation benefits. The simulations examine the same spatial arrangements of open space as in Fig. 1 except that the open spaces no longer offer ambient amenities.

Open space influences the land price gradient much less if the open space does not offer ambient amenities. Only in panel (c) do three contours in the land rents gradient appear, and the three contours are not readily apparent until panel (d). Since recreation trip costs do not rise significantly with distance from the open space, not much crowding occurs around the open space to receive the recreation benefits at a low cost.

The most attractive location now is the CBD. However, the recreation benefits do stimulate some attraction to the open space, raising land prices moderately around them. Since, as the open spaces become closer, the locations near the open space do not become more attractive than the CBD, and the developed area does not shift away from the CBD.

From Table 2, since open space increases utility through recreation trips, utility is higher in cities with open space. Since the open space generates a slightly steeper land rent gradient and the number of households is fixed, housing density rises and the developed area falls.

The net result of land prices rising moderately and the developed area falling is that the total land rents of cities with open space falls. Since recreation trips are costly, less income is available for land and housing. For cities with ambient amenities, total land rents are higher since the ambient amenities increase the attractiveness of locations near the open space at no cost.

The closer proximity of the open spaces makes the equilibrium utility steadily drop. Since there is no double dosage of ambient amenities, the clumping of the open spaces increases the travel costs of recreation for households on the far side of the city. Higher total travel costs of recreation results in lower equilibrium utility.

The recreation benefits make the locations near the open space more attractive than those same locations without open space. Since the locations

Improving Environmental Valuation Estimates Through Consistent Use of Revealed and Stated Preference Information

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Improving Environmental Valuation Estimates Through Consistent Use of Revealed and Stated Preference Information

Abstract

Environmental valuation data from stated and revealed preference methods are integrated into a unified model of preferences for environmental quality improvement that identifies the "use" and "nonuse" components of the total value estimate. This articulates clearly what parts of the total value estimate come from each type of data, and permits tests of whether estimated preferences satisfy weak complementarity between the environmental good of interest and related private goods. The statistical advantages of using more information for the valuation problem are exploited, while retaining flexibility to identify value estimates from any individual method of analysis.

Keywords: Environmental valuation, nonuse value, weak complementarity, stated preference, revealed preference

Improving Environmental Valuation Estimates Through Consistent Use of Revealed and Stated Preference Information

I. Introduction

There is wide recognition that environmental amenities or quality improvements may provide benefits in the form of non-marketed or public goods, and that nonuse or "passive use" value can be an important component of total nonmarket benefits in addition to use value ([30], [42], [19], [3]). Different nonmarket valuation methods have varying capabilities of measuring these nonmarket benefits. For instance, the revealed preference approach measures "use value," the part of the total benefits reflected by changes in (compensated) demands for related private goods. In contrast, the stated preference approach in principle measures the total benefits directly, so captures both use and nonuse value. In addition, it is generally well-appreciated that each individual approach has its own strengths and weaknesses ([13], [37], [41], [4]). Because of this, economists working on nonmarket valuation problems have turned increasingly to the use of multiple methods for assessing environmental values, as has been done elsewhere in the literature ([14], [8], [15], [27]).

One of the most common ways of using multiple methods is to combine actual behavior with statements of value, e.g., by collecting information on recreation trips to a resource whose quality changes and asking respondents their willingness to pay (WTP) for those same quality changes. Trips information is used to estimate a recreation demand function, while WTP responses are used to estimate a WTP function for quality improvements. The demand function provides estimates of use value, while the WTP function gives estimates of the total value of the quality change, which may consist of a nonuse value component in addition to use value.

There are some important reasons why researchers need to pay attention to the use-related and nonuse-related parts of the total value of environmental amenities when using multiple methods for a single valuation problem. One is simply that policymakers may be interested in what part of the value of a resource is related to direct use, and what is nonuse value-related. A more fundamental reason, though, is that in combining data from multiple sources rigorously (i.e., with a coherent underlying model of consumer preferences), one cannot escape having to know what parts of the combined model are being generated from which data. In the example of combining demand and WTP data, since one measures use value and the other measures total value, the two models will have some, but not necessarily all, preference parameters in common.[1] Knowledge of which parameters enter different parts of the model is necessary for theoretically-consistent joint estimation, and is tantamount to knowing the expressions for nonuse (as well as use and total) value. There may also be a statistical advantage of combining data, either from reducing biases to or variance of the estimate of WTP for the quality change ([28]).

Consistency of the modeling approach to a nonmarket valuation problem can be evaluated both in terms of the functional forms used for the demand and WTP functions, and in the internal consistency of the value estimates generated. An adequate empirical model must be able to rationalize both sets of data as consistent with a single underlying model of preferences for use and environmental quality. This means that (a) the functional forms of demand and WTP should be consistent with a utility or expenditure function; (b) the parameters appearing in both the demand and WTP functions should be the same, and satisfy the requirements of choice theory; and (c) the use and nonuse value estimates generated from the model should be internally consistent. In particular, nonuse value should be traceable to parameters that appear only in the WTP function.

While several interesting recent papers have addressed one or more aspects of this problem,[2] none has succeeded completely in developing and estimating an integrated model of demand and WTP to produce internally-consistent estimates of use and nonuse value of environmental quality changes. Cameron [7] estimated a model of demand and WTP based on a quadratic direct utility function, but this model did not produce separate estimates of use and nonuse value. Niklitschek and Leon [40] combined WTP statements with statements of intended use, but the preference function they use explicitly excluded the presence of nonuse value. Huang, Haab, and Whitehead [25] estimate a demand function and a variation function (which generates Marshallian estimates of

WTP), but the functional forms of the two were not internally consistent with a model of preferences.

This paper develops and demonstrates a convenient-to-use, theoretically-consistent empirical framework for estimating use, nonuse, and total values of quality changes by combining revealed (TCM) and stated preference (CVM) data for improvement of environmental quality. Beginning from a commonly-used Marshallian recreation demand function (the semi-log function, which relates log quantities to the levels of covariates) and integrating back to recover the implied quasi-expenditure function, the part of quasi-preferences that may generate nonuse value is identified. By parameterizing this part of preferences (which is the constant of integrating back from demand), and using the resulting empirical form of the quasi-expenditure function to derive compensating variation expressions, functional forms for WTP that are consistent with the demand function are obtained.[3]

The WTP function has parameters associated with both use and nonuse value, while the demand function only contains parameters pertaining to use value. When demand and WTP are jointly estimated using both TCM and CVM data, the stated preference (CVM) responses provide the information needed to estimate the nonuse parameters, while both the stated and revealed (CVM and TCM) responses provide information for estimating use value parameters. The result is a complete characterization of the individual valuation of the quality change, including the total value and the part of this value that will be found in the demand behavior (use value) and the part that is not (nonuse value). It permits several innovations in the empirical estimation of nonuse value, including (a) testing for its presence as restrictions on the parameters of the preference function; and (b) allowing it to vary systematically with individual characteristics, much the way demand does.

This strategy is attractive as it allows the data collected on multiple "windows" to an individual's values to be used consistently within an underlying preference structure. Joint estimation provides more structure for parameter estimation and uses both sources of information more efficiently. It permits an assessment of the use, nonuse, and total value of a quality change without resorting to behavioral restrictions such as often-invoked weak complementarity, which implies zero nonuse value. Instead, whether preferences exhibit weak complementarity is a testable proposition within the model, as a restriction on the nonuse value parameters.[4]

Section II develops the theoretical framework for identifying use and nonuse value and testing for weak complementarity, while Section III lays out the estimation model. The data used in the empirical application are described in Section IV, and Section V presents and discusses the empirical findings. Section VI concludes.

II. Theoretical Framework

The starting point for utility-theoretic analysis is the individual's utility maximization problem, which can be written as

$$\underset{x,\,z}{Max}\ u(x,z,q) \qquad s.t. \qquad m = px + z \tag{1}$$

where for simplicity x is recreational visit frequency with corresponding price p, and z is a numeraire good with unit price. Other goods are suppressed in the notation as a matter of convenience, without loss of generality. The variable q represents a water quality variable and is assumed to be a public good not chosen by the individual, while m is household income. The utility function $u(\cdot)$ is the individual's continuous, differentiable and quasi-concave utility function. Water quality, q, is assumed to be a good, so that it enters the preference structure such that $\partial u/\partial q > 0$.

Solving the constrained utility maximization problem yields the Marshallian demand for trip frequency $x = x(p,q,m)$, which is specified empirically with the semi-log functional form[5]

$$x(p,q,m) = \exp(\alpha + \beta p + \gamma q + \delta m), \tag{2}$$

where α, β, γ, and δ are demand parameters. Substituting this trip demand into the utility function yields the indirect utility function $V(p,q,m) = u(x(p,q,m), z(p,q,m), q)$, whose inverse with respect to income argument is the minimum expenditure function

$$E(p,q,u) \equiv \min_{x,z} \left\{ px + z : u(x,z,q) = u \right\},$$

which is used for measuring welfare changes. Given the assumption that q is a good, $E(p,q,u)$ is decreasing in q (i.e., $\partial E/\partial q < 0$).

When one integrates back to obtain the preferences underlying a given demand function, what is recovered is the *quasi*-expenditure function ([23]), which does not contain all the information about preferences, but which does contain all the relevant information for welfare analysis when own-price p changes ([32]). The reason is that integrating back results in a constant of integration that may depend on other prices and on quality, though not on own price. Depending on how quality enters the constant of integration, preferences may or may not exhibit weak complementarity of q to x (i.e., absence of nonuse value). Demand behavior alone cannot determine this, though stated preference information can.

To obtain the quasi-expenditure function implied by (2), one can note the identity (through Shephard's Lemma) of the price slope of the expenditure function to Hicksian demand, and the identity relating Hicksian demand to Marshallian demand when money income is replaced by the expenditure function:

$$\partial E(p,q,u)/\partial p = x^h(p,q,u) = x(p,q,E(p,q,u)) \tag{3}$$

where $E(p,q,u)$ is the expenditure function and $x^h(p,q,u)$ is the Hicksian or compensated demand function.

Given the semi-log specification of trip demand x, equation (3) solves for the quasi-expenditure function

$$\widetilde{E}(p,q,\theta(q,u)) = -\frac{1}{\delta}ln\Big(-\frac{\delta}{\beta}e^{(\alpha+\beta p+\gamma q)} - \delta\theta(q,u)\Big) \tag{4}$$

where $\theta(q,u)$ is the constant of integration that, in general, depends on quality q ([21], [23]). If one were concerned only about the welfare consequences of own-price changes, as in Hausman [23], $\theta(q,u)$ could be set to the utility index u. As it happens, that particular parameterization of $\theta(q,u)$ implies weak complementarity of x and q for the semilog demand function.[6] In general, however, one would expect $\theta(q,u)$ to be a function of q, and, consequently, for there to be nonuse value. Thus $\theta(q,u)$ is the source of nonuse value in the semilog demand model.

In anticipation that CVM responses can be used to identify the parameters of nonuse value, it is logical to specify $\theta(q,u)$ as a function of q and u. For this analysis, it is assumed that $\theta(q,u) = e^{\delta\psi q}u$.[7] Substituting this into (4), the empirical form of quasi-expenditure consistent with the semilog demand in (2) is

$$\widetilde{E}(p,q,u) = -\frac{1}{\delta}ln\Big(-\frac{\delta}{\beta}e^{\alpha+\beta p+\gamma q} - \delta e^{\delta\psi q}u\Big) \tag{5}$$

This quasi-expenditure function is defined for $0 \leq x <$ -β/δ; i.e., $e_{pp} < 0$ and $x \geq 0$ over this range. The quasi-indirect utility function corresponding to (5) is

$$\widetilde{V}(p,q,m) = \Big(-\frac{1}{\delta}e^{-\delta m} - \frac{1}{\beta}e^{\alpha+\beta p+\gamma q}\Big)e^{-\delta\psi q}. \tag{6}$$

It is notable that no preference restrictions (such as weak complementarity) are imposed on this expenditure function [other than the functional form for $\theta(q,u)$], so that depending on the value of ψ, there may be nonuse value in addition to use value. As seen formally below, if the hypothesis that $\psi = 0$ is rejected, nonuse value is present in the estimated preferences.

Measures of Total, Use, and Nonuse Value

Now suppose water quality is improved from q^0 to q^1 due to the implementation of a government policy. Measures of use, nonuse, and total value of this quality improvement can be obtained from the quasi-expenditure function. Individuals' WTP for, or total value (TV) of, this quality change can be represented by a compensating variation measure, defined as the maximum amount of income that individuals would give up in order to enjoy the quality improvement, holding utility constant. It can be expressed as the change in the expenditure function as quality changes from q^0 to q^1 given utility is held constant at the reference level u_0, which is determined from equation (6) evaluated at the initial quality level,

$$u_0 = \Big(- \tfrac{1}{\delta} e^{-\delta m} - \tfrac{1}{\beta} e^{\alpha + \beta p + \gamma q^0} \Big) e^{-\delta \psi q^0}. \tag{7}$$

Using (7) in (6), the total value of the quality change is[8]

$$TV(q^0, q^1) = \widetilde{E}(p^0, q^0, u_0) - \widetilde{E}(p^0, q^1, u_0)$$

$$= \tfrac{1}{\delta} \, ln \Big[- \tfrac{\delta}{\beta} e^{(\alpha + \beta p + \gamma q^1 + \delta m)} + (1 + \tfrac{\delta}{\beta} e^{\alpha + \beta p + \gamma q^0 + \delta m}) e^{\delta \psi (q^1 - q^0)} \Big) \Big]. \tag{8}$$

Equation (8) is the expression for willingness to pay by the recreationist responding to a valuation question. Upon noting that $e^{(\alpha+\beta p+\gamma q^1+\delta m)} = x^1$ is the Marshallian quantity demanded after the quality change and $e^{\alpha+\beta p+\gamma q^0+\delta m} = x^0$ is Marshallian quantity demanded before the quality change, total value can be written succinctly as

$$TV(q^0, q^1) = \tfrac{1}{\delta}\, ln\Big[-\tfrac{\delta}{\beta} x^1 + (1 + \tfrac{\delta}{\beta} x^0) e^{\delta\psi(q^1 - q^0)} \Big]. \tag{9}$$

A comparison of the TV expression in equation (9) with the demand function in equation (2) confirms that ψ is central to "nonuse" value as it doesn't appear in the demand function. In fact, (9) makes quite clear the parts of TV that do depend on demand (x^0, x^1, and the parameters β and δ), as well as that (the arguments of ψ) which does not.

To develop a joint estimating model which combines CVM information on total value with TCM data on use value, it is necessary to articulate more precisely the way in which (9) encompasses use and nonuse values, respectively. The standard decomposition of total value into use and nonuse components follows the logic of Mäler [34] and McConnell [35], which involves adding and subtracting the terms $\widetilde{E}(\widehat{p}^0, q^0, u_0)$ and $\widetilde{E}(\widehat{p}^0, q^1, u_0)$ from (7), with $\widehat{p}^0$ and $\widehat{p}^1$ being the Hicksian choke prices given the initial and subsequent quality levels. Terms then can be grouped as

$$\begin{aligned} TV(q^0, q^1) = &\Big\{ [\widetilde{E}(\widehat{p}^1, q^1, u_0) - \widetilde{E}(p^0, q^1, u_0)] - [\widetilde{E}(\widehat{p}^0, q^0, u_0) - \widetilde{E}(p^0, q^0, u_0)] \Big\} \\ &+ \Big\{ \widetilde{E}(\widehat{p}^0, q^0, u_0) - \widetilde{E}(\widehat{p}^1, q^1, u_0) \Big\} \end{aligned} \tag{10}$$

$$= \Big\{ \int_{p^0}^{\widehat{p}^1} x^h(p, q^1, u_0)dp - \int_{p^0}^{\widehat{p}^0} x^h(p, q^0, u_0)dp \Big\} + \int_{q^1}^{q^0} \frac{\partial \widetilde{E}(\widehat{p}, q, u_0)}{\partial q} dq$$

$$= UV(q^0, q^1) \; + \; NUV(q^0, q^1). \tag{11}$$

The first term in equation (11), $UV(q^0, q^1)$, is "use value," the difference in areas under the Hicksian demand as it shifts with the quality change; it is the Hicksian counterpart to the change in consumer's surplus one would calculate with a demand shift. The second term in (11), "nonuse value," is the difference in minimum expenditure for the quality change given that x is not being consumed; this is the part of total value unrelated to use of x.

To determine the mathematical expressions for use and nonuse value corresponding to the empirical semilog demand function in (2), the expressions for $\widetilde{E}(\widehat{p}^0, q^0, u_0)$ and $\widetilde{E}(\widehat{p}^0, q^1, u_0)$, are needed. To obtain these, note that the Hicksian demand, obtained by differentiating (5) with respect to p, is

$$x^h(p, q, \theta(q,u)) = e^{(\alpha+\beta p+\gamma q)}/[-\tfrac{\delta}{\beta}e^{(\alpha+\beta p+\gamma q)} - \delta g(q)u]. \tag{12}$$

The denominator of (12) is strictly positive since Hicksian quantities are positive and finite. This means that the Hicksian choke price $\widehat{p}(q,u) \equiv min\{p : x^h(p,q,u) = 0\}$ is infinity (provided the own-price coefficient β is negative) for all q. Substituting this into the quasi-expenditure function, when x is not being consumed the quasi-expenditure function is

$$\widetilde{E}(\widehat{p}(q,u), q, \theta(q,u)) = -\tfrac{1}{\delta}ln[-\delta e^{\delta\psi q}u]. \tag{13}$$

Thus nonuse value for this quasi-expenditure function is

$$\begin{aligned} NUV(q^0, q^1) &= \widetilde{E}(\widehat{p}^0, q^0, u_0) - \widetilde{E}(\widehat{p}^1, q^1, u_0) \\ &= -\tfrac{1}{\delta}ln[-\delta e^{\delta\psi q^0}u_0] + \tfrac{1}{\delta}ln[-\delta e^{\delta\psi q^1}u_0] \\ &= \psi[q^1 - q^0] \end{aligned} \tag{14}$$

since the term $\frac{1}{\delta}ln[-\delta u_0]$ cancels from both expenditure function terms.

Use value can then be determined either by the first four expenditure function terms in equation (10),[9] or by subtracting nonuse value [equation (14)] from total value [equation (8)]:

$$UV(q^0, q^1) = TV(q^0, q^1) - NUV(q^0, q^1)$$

$$= \tfrac{1}{\delta} ln\Big[-\tfrac{\delta}{\beta}x^1 + (1 + \tfrac{\delta}{\beta}x^0)e^{\delta\psi(q^1-q^0)}\Big] - \psi\,[q^1 - q^0].$$

Dividing the argument of the natural logarithm by $e^{\delta\psi(q^1-q^0)}$ and extracting this term from the natural logarithm, the expression for use value simplifies to

$$UV(q^0, q^1) \; = \tfrac{1}{\delta} ln\Big[-\tfrac{\delta}{\beta}x^1 e^{-\delta\psi(q^1-q^0)} + (1 + \tfrac{\delta}{\beta}x^0)\Big]. \tag{15}$$

Use value in equation (15) contains the non-use value term ψ; this is the reason why some behavioral assumption, like weak complementarity, is necessary to measure use value. As Bockstael and McConnell [5] pointed out, when quality changes, the amount by which Marshallian demand shifts is known from the demand function, but the amount by which the Hicksian demand (the basis for measuring use value) shifts cannot be determined from demand alone. Herriges, Kling, and Phaneuf [24] echo the often-overlooked point that one cannot even measure use value from revealed preference information alone without some unverifiable assumption about preferences, *and* that the magnitude of use value (as well as nonuse value) depends on that assumption. Equation (15) makes clear that use value will vary depending on what is assumed about ψ.

A number of previous papers have made a behavioral assumption about preferences, which is tanatamount to choosing the value for ψ ([33]). The empirical approach of this paper is to combine data from both CVM and TCM to estimate ψ along with the demand parameters. This avoids the need to impose *a priori* restrictions on how quality affects preferences (aside from the usual maintained hypothesis about functional form.)

Testing for Weak Complementarity

Before turning to the empirical model, it is useful to verify the use and nonuse value that arise under weak complementarity. Quasi-preferences are weakly complementary if they satisfy $\partial \widetilde{E}(\widehat{p}, q, \theta(q,u))/\partial q = 0$ ([34], [35]); that is, the quasi-expenditure function does not change as quality changes when the weakly complementary good (x in this case) is not consumed—that is, when its price is the Hicksian choke price $\widehat{p}$. The quasi-expenditure function when x is not consumed is given in equation (13), and its derivative with respect to quality is

$$\partial \widetilde{E}(\widehat{p}, q, \theta(q,u))/\partial q = \; -\psi \tag{16}$$

which is zero when $\psi = 0$.[10] Under this condition, preferences exhibit weak complementarity, and use and nonuse value are, from (15) and (14) respectively,

$$UV(q^0, q^1) \; = \tfrac{1}{\delta} ln\Big[1 - \tfrac{\delta}{\beta}(x^1 - x^0)\Big]$$

$$NUV(q^0, q^1) = 0.$$

The hypothesis test $H_0 : \psi = 0$ is, therefore, a test for whether preferences satisfy weak complementarity (and nonuse value is zero) within this model. It is important to emphasize that this is a joint test of both the functional form for preferences and for the absence of nonuse value.

This result is consistent with the analysis of Herriges, Kling, and Phaneuf [24], who also point out that one cannot test for weak complementarity from revealed preference data alone. The parameter ψ appears in WTP but not in demand, so demand behavior is not sufficient to identify it. However, as Ebert [17] noted, one way to identify the full value of a quality change (and estimate ψ) is to introduce information about the inverse demand for quality, and CVM can be used for this purpose. Thus, by combining revealed and stated preference data, one can test whether weak complementarity holds, and distinguish which of the (infinitely-many) utility functions consistent with the revealed preference data is also consistent with the stated preference data.

III. Estimation Model

The data used in the empirical application of the use-nonuse value estimation methodology (explained more fully in the next section) were collected from recreational users of the Man Kyoung River basin in South Korea. Respondents were asked about their river use, and answered a sequence of questions about whether they were willing to pay specific amounts of money for river water quality improvement. Since they actively made two behavioral decisions, how many trips to take and their WTP for water quality improvements, one can reasonably assume that both are motivated by the same preference structure. These individuals' total valuation of a water quality improvement may contain both use value and nonuse value.[11] Adopting a unified preference structure for analysis provides an opportunity to jointly estimate the actual recreation demand and contingent WTP models, and to evaluate formally whether or not nonuse value plays a major part in the WTP for water quality improvement.

Use value, in our context, is the change in net economic value associated with increases in the demand for visits to recreational sites in the Man Kyoung River basin. Nonuse value is the component of total value that arises independent of use. This approach to defining nonuse value allows for the possibility that users as well as nonusers might hold values that are independent of use ([19]).

For estimation, equations (2) and (9) are assumed to represent the systematic part of preferences. The demand parameters α, β, γ, and δ appear in both the demand and WTP functions [equations (2) and (8)], while the nonuse-related parameter ψ enters only into the stated WTP function [equation (8)]. Appending a demand error η and a WTP error ϵ, the system of equations to be estimated can be written as

$$ln[x(p,q,m)] = \alpha + \beta p + \gamma q + \delta m + \eta \quad (17)$$

$$WTP = \frac{1}{\delta} ln\Big[-\frac{\delta}{\beta} e^{(\alpha+\beta p+\gamma q^1+\delta m)} + \big(1 + \frac{\delta}{\beta} e^{\alpha+\beta p+\gamma q^0+\delta m}\big) e^{\delta\psi(q^1-q^0)}\Big)\Big] + \epsilon$$

$$= TV + \epsilon.$$

The errors η and ϵ would not be expected to be identical because they pertain to different decisions made over different time periods (trips over the course of a year, and a value statement at a later point in time). It is likely, though, that some unobservable factors associated with the two decisions (e.g., effects of omitted demographics or attitudinal information) are part of both errors, which suggests a likely correlation between them. Thus, η and ϵ are assumed to follow a bivariate normal distribution $N(0, 0, \sigma_\eta^2, \sigma_\epsilon^2, \rho)$ with different scale parameters (σ_η^2 and σ_ϵ^2) and correlation ρ[12].

The Empirical WTP-Demand Model

The CVM portion of the survey followed a double-bounded (DB) format, with an initial yes-no response to an initial bid, with a followup yes-no question to a second bid that was higher or lower than the first, depending on the person's response to the first question. In this discrete CVM question with follow-up format, response combinations are *yes/yes, yes/no, no/yes, and no/no* for a sequence of two bids, t_1 and t_2, presented to a respondent to bound WTP. Using an experimental design in the survey, if a respondent answered *yes* to the first bid amount, he/she was offered with higher bid amount in the second WTP question ($t_2 > t_1$). Likewise, a respondent saying *no* for the first bid was assigned with lower bid amount for the second WTP question ($t_2 < t_1$).

In light of concerns about incentive compatibility of the second WTP question in double-bounded formats (e.g., [6], [1]), we use the answers to the first WTP question only and estimate a single-bound (SB) dichotomous choice WTP model jointly with demand.[13] Probability functions for the two WTP response patterns are $P(yes) = P(WTP > t_1)$ and $P(no) = P(WTP < t_1)$.

Combining respondents' actual numbers of trips taken and WTP responses, the likelihood function for the joint decisions is

$$\mathcal{L} = \prod_{i \in no} P(x, no) \prod_{j \in yes} P(x, yes) \tag{18}$$

The joint distribution of the first term in equation (18), $P(x, no)$, can be written as the product of the conditional distribution of a no CVM response given x trips taken, $P(no|x)$, and the marginal distribution of trips, $\phi(x)$. Extending this decomposition to the other outcome, the likelihood function can be rewritten as

$$\mathcal{L} = \prod_{j \in no} \phi(x) P(WTP < t_1|x) \prod_{k \in yes} \phi(x) P(WTP > t_1|x) \tag{19}$$

where $\phi(\cdot)$ is the normal density function. In the first term of equation (19), the conditional probability function of no given x can be written as[14]

$$P(WTP < t_1|x) = P(TV + \epsilon < t_1|x) = P(\tfrac{\epsilon}{\sigma_\epsilon} < \tfrac{t_1 - TV}{\sigma_\epsilon}|x)$$

$$= \Phi\left(\frac{((t_1 - TV)/\sigma_\epsilon) - \rho(\eta/\sigma_\eta)}{(1-\rho^2)^{1/2}}\right)$$

where $\Phi(\cdot)$ is a standard univariate normal cumulative distribution function.

Applying this process to other response category of equation (19), the log likelihood function of the joint decisions associated with actual trip demand and contingent WTP responses can be expressed as

$$Log\,\mathcal{L} = -\frac{n}{2} log(2\pi\sigma_\eta^2) - \frac{1}{2}\sum_{i=1}^{n}\left[\frac{lnx - (\alpha + \beta p + \gamma q + \delta m)}{\sigma_\eta}\right]^2 + \sum_{i=1}^{n}(1 - I_1)\, log\left[\Phi\left(\frac{((t_1 - TV)/\sigma_\epsilon) - \rho(\eta/\sigma_\eta)}{(1-\rho^2)^{1/2}}\right)\right]$$

$$+ \sum_{i=1}^{n} I_1 \, log \left[1 - \Phi\left(\frac{((t_1 - TV)/\sigma_\epsilon) - \rho(\eta/\sigma_\eta)}{(1-\rho^2)^{1/2}} \right) \right] \tag{20}$$

where TV is defined in equation (8), and $\eta = lnx - (\alpha + \beta p + \gamma q + \delta m)$, from equation (17). The variable I_1 is a dummy indicator for the discrete WTP response (1 for yes, 0 for no).

The distinctive feature of the likelihood function in (20) is that two behavioral responses—trips taken and responses to WTP questions—are derived from a unified underlying preference structure, allowing cross-equation restrictions on parameters of the recreation demand model and the WTP function. The parameters of (20) were estimated using the maximum likelihood module of GAUSS.

IV. Data

The joint model of combined revealed and stated preferences is illustrated by a case study of the Man Kyoung River (MKR) basin located in Korea. The Man Kyoung River originates inland in Cholla Buk Do province and is joined by several branch streams before reaching the Yellow Sea. The MKR provides irrigation water for agriculture in the province as well as recreational sites for a million people residing within the river basin. Recently, concern has been growing about deterioration of water quality of the MKR due to sewage and industrial waste water from urban areas, along with livestock manure and other runoffs from agricultural farms.

Water quality standards for surface waters in Korea follow a five-tier system. Class I water is considered *drinkable* when boiled. Class II is *swimmable* waters, and people would be safe swimming in the river. Class III water is *fishable*, in that game fish can survive in the water and be eaten without endangering human health. Water in Class IV is *boatable*, and people would not experience harm to their health if they fell into the river for a short time while boating. Water in Class V does not allow any of these activities ([38]).

Over the years, waters in the downstream reaches of the MKR have been graded to be Class V, which designates water quality not good enough even for agricultural use. Especially recently, water quality levels of the MKR have been at the center of a controversy associated with a large reclamation project, the Sae Man Kum Project.

The Sae Man Kum project is a large-scale reclamation project which is designed to construct a 33 km dike downstream of the MKR during the period 1991-2006. The completion of the dike is expected to create some 40,100 hectares (ha) of reclaimed land: agricultural land of approximately 28,300 ha and a man-made lake of some 11,800 ha. However, there has been outrage and apprehension that the man-made lake will be dead within just a few years if polluted water from the MKR, which is upstream of the lake, continues to flow into it. In response to those concerns, the government—at both local and federal levels—initiated cleanup plans to improve water quality of the MKR to the level of Class II (swimmable). Since the government anticipates that those plans will cost at least $450 million,[15] it is important to compare these costs with the value that residents in the river basin place on the water quality improvement.

To elicit economic benefits associated with the improvement of water quality in the MKR, an in-person household survey of residents along the MKR basin was conducted during October and November of 2000. This river basin encompasses 4 cities and 1 county across the Chonbuk province, which constitute the sampling areas. The sample of residents over 20 years old (excluding students) was allocated across the 5 sampling areas according to the age and gender distributions of each. Interviewers first screened respondents based on these criteria, and if the respondent met the desired criteria the interview continued. Cooperation rate (defined as the number of interviews that were completed once respondents met the screening criteria, was approximately 85%. This relatively high rate that is attributable in part to cultural factors, and resulted in a total of 510 usable surveys from users of the MKR. Information was collected on respondents' actual recreational use, their subjective perceptions and knowledge about water pollution of the MKR, contingent valuation questions for improved water quality and debriefing questions, and other economic and demographic characteristics.

Recreation Demand and Travel Costs

To obtain revealed preference data associated with recreational use of the MKR, recreational participation and visit frequency for the previous year were elicited for six sites that stretched from upper tributaries to downstream reaches of the MKR. The main recreational activities enjoyed at those six sites are swimming, playing in the water, family picnics, and fishing. The six sites could be considered substitutes for each other but are differentiated by water quality. Water quality of each site was matched with an objective quality indicator, the annual average biochemical oxygen demand (BOD) level,[16] which is the amount of oxygen required to decompose organic material under specified temperature conditions.[17] Respondents in the sample had visited at least one of the six sites along the MKR during the previous year, and were considered as users of the MKR and formed the sample for the empirical evaluation of our approach to combining data for estimation of the preferences that generate both types of responses.

As mentioned earlier, recreational activities enjoyed at each of the six sites are mainly swimming, playing in the water, family picnicking, and fishing, and thus the six sites were considered to be close substitutes for each other. Therefore recreation demand functions were estimated based on the number of visits to a "typical site," where the typical site is defined to be the site most frequently visited by a respondent[18] ([9], [19]). To reflect the variation in the water quality variable among respondents, the annual mean of BOD for a respondent's typical site was used as the water quality variable for that respondent. Also, the changes in water quality presented in the CVM questions (i.e. from Class V to Class II) were converted into changes in BOD levels.

As a price variable, travel costs were measured by the sum of the money and time cost of travel to the site.[19] Round trip distance was measured from the map using respondents' detailed residence information. The opportunity cost of time was assumed to be a fraction (30%) of respondents' wages ([10]). Respondents' wage rates were calculated based on their occupation, which was elicited in the survey. The average wage of each occupation category was weighted by the respondent's gender, education and experience.[20] Imputed hourly wages ranged from $2.19 to

$22.17. The opportunity costs of housewives, students and unemployed respondents were assumed to be zero. Household income was constructed as the sum of monetary income before taxes and the monetized time budget, using the assumed opportunity cost of time.

Willingness to Pay for Water Quality Improvement

Following questions eliciting respondents' knowledge of, and subjective perceptions about, water pollution levels of the MKR, respondents were presented with a map of the Man Kyoung River area in which each branch stream was depicted with different colors depending on its water quality level. After looking at the map, respondents were provided with up-to-date information about the MKR area, including water pollution levels downstream, causes of water degradation, and potential government policies to clean up the river system. The status quo water quality level of downstream reaches was described to be worse than Class V according to the river water quality standards, with the additional information that no use for fishing, swimming, or other water contact was possible.[21]

Because of controversies among experts about whether the government policies would achieve the goal of improving water quality of the MKR to swimmable (Class II), the sample was divided into two groups that received different versions of water quality improvement levels. One treatment informed respondents that the government policy implementation would improve water quality downstream in the MKR to Class II (*swimmable*) levels, while in the other, water quality would be improved to Class III (*fishable*) level.

In addition to verbal explanations of the current and improved water quality levels, interviewers showed respondents a water quality ladder as a visual aid to help them understand the relative changes in water quality. In light of focus group responses and pre-test results, the payment vehicle chosen was monthly charges for water quality improvement as a specifically-designed object tax, which would continue in perpetuity. After reminding respondents to consider their household income and expenditures (following the NOAA panel's recommendations), respondents were asked if they would pay the suggested monthly charges. In the experimental design, respondents were randomly assigned one of 10 bid values ranging from 75 cents to $23 per month.

In jointly estimating the same parameters for WTP and demand, it is necessary for the time dimension of each to match. Since trips taken were on an annual basis, compensating variation measures from the demand function are annual measures. To match up the SP data with the RP data, annual WTP estimates are needed. These are obtained by using annual WTP bids (monthly WTP bids multiplied by 12) in the joint demand-WTP estimation.[22]

Following debriefing questions to identify reasons why people did not wish to pay for improved water quality, respondents were asked to state which level of water quality they thought would be achieved (Class II or Class III) if the government policy programs were implemented. Table 1 defines the variables used in the analysis and provides summary statistics.

V. Results

Table 2 reports the results of the joint estimation of actual recreation demand and contingent WTP functions. To generate a specification that allows for the possibility of nonuse value, the nonuse parameter ψ was allowed to vary with individual characteristics, as $\psi = (\sum_k \psi_k \mathrm{D}_k)^2$, where D_k is the k^{th} demographic characteristic (with $\mathrm{D}_0 \equiv 1$ so that ψ_0 is a constant). This specification imposes the requirement that nonuse value be non-negative, which is justified both by theory and intuition.[23] Then the hypothesis of weak complementarity between demand and water quality changes was made, as a restricted version of the model with H_0: $\psi_k = 0 \; \forall k$.

Overall, most explanatory variables significantly influenced both trip demands and WTP functions with the expected signs. Travel cost had significant negative effects on both the number of visits to the typical site and on the probability of being willing to pay a given bid amount. Full income had a positive effect on demand and WTP, and was significant at the 5% level in the weakly complementary model and the 15% level in the nonuse value model. Water quality was highly significant in both decisions too; better water quality induced more frequent trips to the site as well as a higher probability of saying *yes* to the CVM question(s). *Memory*, a dummy variable with a value of 1 for respondents who had memories of swimming along the MKR in their youth, also was significant, with more frequent visits and a correspondingly higher use value for water quality improvements.

Memory also was a significant explainer of the nonuse value term. Two other significant demographic factors were *Urban*, a dummy variable indicating residence in one of the three cities in the sample; and *Child*Gender*, where *Child* is the number of children in the household and *Gender* is a dummy variable indicating whether the respondent is male or not. A variety of other demographic shifters were explored for both the use and nonuse value parts of preferences, but none of these provided any greater explanatory power for either demand or WTP.

Tests for Weak Complementarity of Preferences

As noted in Section II, the test for weak complementarity is to evaluate whether the null hypothesis H_0: $\psi = 0$ holds within the model. The χ^2 test statistic for the likelihood ratio test of the restriction $\psi = 0$ is 14.55 (Table 2), which exceeds the critical $\chi^2_{.95,4df}$ of 9.49. Thus, the hypothesis that preferences satisfy weak complementarity is rejected for this model.

The Use and Non-Use Values of a Water Quality Improvement

Based on the nonuse value models of Table 2, welfare measures of water quality improvement are presented in Table 3. The total value that users place on the water quality improvement is estimated for two policy relevant changes: the improvement to *fishable* level, a 4 parts per million (ppm) reduction in BOD, and to *swimmable* level (a 7 ppm reduction). Using equations (14) and (15), total value estimates were decomposed into use values and non-use values.

Annual total WTP to restore water quality to the *Fishable* level was $26.56. Standard errors were simulated based on the Krinsky-Robb approach using means of the covariates and 10,000 draws. Use value was \$16.35, while nonuse value was estimated to be \$10.21. All of these estimates are significantly different from zero at the 95% level (using a single-tailed test).

For improvements in water quality to the *Swimmable* level, the total WTP was \$47.64, of which use value was \$29.78 and nonuse value was \$17.86. As with the improvement to fishable, all estimates are significantly different from zero.

The statistically significant nonuse value for river users is noteworthy. This should be interpreted as saying that the two valuation methodologies produce distinctly different estimates of the value of a water quality change by users of the MKR. When they are reconciled within a unified model of preferences, the nonuse value is the estimate of the magnitude of this systematic difference, and implies that MKR users include more than just their use value in their statements of WTP for water quality improvements. This is consistent with the fact that the revealed and stated preference approaches identify different parts of the value of water quality improvement .

VI. Concluding Remarks

This paper has developed and demonstrated a convenient, utility-theoretic approach to combine information from revealed and stated preference data in assessing the total value of environmental quality improvements. The approach begins with a statement of behavior, via a demand function. Integrating back identifies the underlying quasi-expenditure function, in particular the preference parameters related to use and nonuse value. The quasi-expenditure function is used to define the compensating variation of a quality change, which is the willingness to pay that individuals express in stated preference experiments such as contingent valuation.

This leads to a two-equation system that represents preferences for environmental quality, as expressed in both the individual's behavior and in their statements of willingness to pay. Because the preference parameters pertaining to use value and to nonuse value are known, an exact decomposition of willingness to pay into both use and nonuse value is possible. This decomposition is particularly useful in matching data collected by different methods for the same valuation problem, because the nonuse value component comes solely from the stated preference data, while the use value component comes from both stated and revealed preference data.

A notable feature of our modeling approach is that several hypotheses can be tested conveniently as parametric restrictions on the model. These include (a) whether weak complementarity holds, and (b) how nonuse value of users varies systematically with individual characteristics.

The method was applied to an important case study on the Man Kyoung River system in Korea, where a public reclamation project affects water quality and, therefore, current users' recreation behavior and their WTP for water quality improvement. The preference parameters of Man Kyoung River basin users relating to both recreation demand and WTP functions were recovered by jointly estimating revealed preference (travel cost) with stated preference (contingent valuation) data.

Relevant economic variables such as price (both travel costs and bid amount) and income had significant influence on both recreation demand and WTP for water quality improvement as anticipated by the economic theory. Water quality of the typical site for each respondent had significant impact on trip frequencies to the site, and the scope of water quality improvement conveyed in the CV question also had significant influence on respondents' WTP.

Comparing the model that allows for nonuse value with the model that does not, the hypothesis that recreation travel is weakly complementary with water quality was rejected. Annual total willingness to pay for an improvement in water quality from status quo (unsatisfactory for agricultural use) to fishable and swimmable was \$27 and \$48. Use values (i.e., the part of these amounts accounted for by changes in demand) were \$16 and \$30, while nonuse value was \$10 for improvement to fishable and \$18 for improvement to swimmable. All these estimates are statistically different from zero. These results are, of course, dependent on our specification of preferences, which consists of both the nonuse term and the demand function.

The point of identifying the (use and nonuse) components of total value for users is to identify precisely how the two types of data must be matched in a given model of preferences.

While it is interesting to note that users can demonstrate statistically-significant nonuse value, as predicted by theory (e.g., [19]), the real significance is in helping to better understand systematically what is measured by revealed preference data and what is measured by stated preference surveys. When the two types of data are matched in a theoretically-consistent and rigorous way, better statistical fits are possible because allowance is made for how value estimates from the two types of data might differ systematically, and more information is used in estimation.

The empirical application in this study was to users of the Man Kyoung River because of the focus on combining stated and revealed preference data. The preference model, based on semilog demand, is consistent with this purpose. A natural generalization would be to estimate preferences for both users and nonusers, accounting for the participation decision. To do this, a demand model that allows for nonparticipation is needed. Given data on multiple demands or willingness to pay for quality characteristics, utility-theoretic demand systems ([12], [44]) can be used to identify and estimate the individual-specific nonuse values that explain differences between the revealed and stated preference data. Finally, while our specification is theoretically consistent in that the systematic parts of demand and WTP are traceable to the same underlying preferences, it is possible to improve on this by a more consistent treatment of error structure along the lines of the analysis by Dubin and McFadden [14].

Footnotes

1. Generally all the demand parameters will also appear in WTP, but WTP may also depend on parameters not shared with demand.
2. These include Adamowicz, Louviere, and Williams [2], Cameron [7], Dickie, Fisher, and Gerking [11], Earnhart [16], Eom and Smith [18], Haener, Boxall and Adamowicz [20], Huang, Haab, and Whitehead [25], and Niklitschek and Leon [40].
3. One could also do this by specifying an expenditure or utility function for preferences and deriving the associated demand(s). In practice, this may not be as transparent a way of identifying the class of functions that can represent nonuse value in a given preference function; this is identified directly by the constant of integration in the integrating back approach.
4. This contrasts with the analysis of Herriges, Kling, and Phaneuf [24], who point out that when one combines information from two revealed preference methods, weak complementarity cannot be tested for. This is discussed in more detail below.
5. Among commonly used simple functional forms for single-equation demands (such as linear, quadratic, and Cobb-Douglas), researchers have often concluded that semilog functions perform better in terms of goodness-of-fit and the magnitude of estimated welfare measures ([45], [36], [43]). Integrating back to recover quasi-preferences is also straightforward ([31]).
6. This point is demonstrated formally below.
7. For incomplete demand systems there are many quasi-expenditure functions, differing only in the form of $\theta(q,u)$ (i.e., in the nonuse value specification), that generate the same demands ([32]). Given a functional form for nonuse value, the data determine parameter values that best explain observed choices and stated preferences. Our empirical analysis treats ψ as a function of individual characteristics to provide considerable flexibility in the nonuse value specification.
8. The full derivation of equation (8) is omitted for brevity since the results for this functional form for preferences are well known ([21], [23], [31]).
9. It is straightforward to verify this using the quasi-expenditure functions in equations (5) and (13) evaluated at the appropriate arguments.
10. More generally, weak complementarity holds for these preferences when $\partial\theta(q,u)/\partial q = 0$, since $\widetilde{E}(\widehat{p}, q, \theta(q,u)) = -\frac{1}{\delta} ln[-\delta\theta(q,u)]$ and the weak complementarity condition is $\partial\widetilde{E}(\widehat{p}, q, \theta(q,u))/\partial q = 0$.

11. Including nonusers would likely provide more information about nonuse value, but would be of limited help in evaluating the approach for combining data that is our principal interest. It would be necessary to make the (strong) assumption that they are identical to users and took no trips only for reasons of price, not because of differences in preferences.
12. This approach links the systematic parts of the two random variables, trips and WTP, as required by theory, but not their error terms. Another strategy would be to append the error η to the demands in equation (9) to obtain an expression for WTP error, but this would not account for other errors that are specific only to the formulation of a WTP response. For example, the WTP statement may be affected by how tightly the current period budget binds, or the information difference between the time at which trips were decided upon and the time at which WTP is stated. Accounting for the relationship between demand and WTP errors by estimating their correlation is a compromise that helps keep the model tractable.
13. Generally when results from the SB and DB approaches differ, the SB is recommended as being less subject to bias from response incentive effects, and typically also generates higher WTP estimates. We examined the double bounded (DB) dichotomous choice WTP-demand model, and (as is often reported in the literature) its WTP estimates were lower than for the SB-demand model. Ninety-five percent confidence intervals for WTP did not overlap for the DB-demand and SB-demand models when weak complementarity was assumed, while they did overlap in the models with nonuse value.
14. The conditional distribution of y given x has a normal distribution with mean $\mu_y + \frac{\rho\sigma_y}{\sigma_x}(x - \mu_x)$, and variance $(1 - \rho^2)\sigma_y^2$.
15. At the exchange rate (1,300 won/US$1) when the survey was conducted (November 2000).
16. The quantitative standards for maximum BOD levels corresponding to different classes of water quality are: 1 ppm (mg/l) for Class I, 3 ppm for Class II, 6 ppm for Class III, 8 ppm for Class IV, and 10 ppm for Class V ([38]).
17. BOD is a widely-used way of measuring surface water pollution levels. While dissolved oxygen (DO) might be a preferred measure of water quality in some settings, there are some advantages to using BOD. First, it is the water quality measure that the public is more familiar with since BOD levels are regularly reported to the public by the news media. Also, under the current water quality act in Korea, BOD levels provide a better distinction between the Swimmable (Class II) and Fishable (Class III) water quality levels. Consultations with environmental scientists indicated that BOD is a fairly good proxy for DO in the MKR region, since the region's effluent is mainly organic wastes from residential wastewater as opposed to industrial discharges.

18. This choice was made because of the definition of the water quality variable, which was an annual average of BOD. It would not be possible to identify quality parameters in demand that motivate site choices in a full six-site system, since there would be no variation in site quality across respondents.
19. Most respondents in the sample spent about a half day at the sites they visited. Since there was not much variation in on-site time among respondents, we decided not to include their on-site time costs as part of travel costs.
20. Average wage by occupation and weights for gender, education and experience were based on "tables for average monthly wage by occupation, gender, and experience" in the 1999 *Statistical Report for Wage Structure* ([39]).
21. Focus group participants found it easier to connect water quality standards with allowable activities than with BOD levels. To reflect this, the water quality ladder presented to respondents added the descriptions of allowable activities for each class of water.
22. Monthly WTP can be problematic for measuring *total* project WTP due to individual differences in discount rates and beliefs about project duration, among other factors, but the annual WTP bids used in estimation and annual WTP measures that result should not be so susceptible to this problem.
23. Equation (16) shows that the restriction that $\psi \geq 0$ is the mild assertion that the quality change is not a bad when the individual is not consuming recreation trips. All the literature that discusses nonuse value presumes that it is non-negative (e.g., [30], [34], [19]).

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