Using the travel cost method to link waterfowl hunting to agricultural activities

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Analyse des relations existant entre les activités agricoles et la chasse au gibier d'eau par la méthode des coûts de transport

Résumé – Cet article montre comment la méthode des coûts de transport (MCT) permet d'analyser les relations existant entre les pratiques agricoles et le bien-être associé aux activités de loisirs. Dans la première partie, on présente les fondements théoriques de la MCT et la façon dont elle peut être utilisée efficacement. Ensuite, deux études de cas illustrent cette problématique. La première concerne les effets produits par l'écoulement d'une eau d'irrigation chargée de sélénium sur la chasse au gibier d'eau dans la réserve naturelle de Kesterson. La seconde compare la valeur de l'eau selon qu'elle est utilisée à des fins de loisirs ou destinée à l'agriculture dans la vallée de San Joaquin en Californie.

Dans les deux cas, on analyse la réaction de la demande, évaluée par la MCT, à la modification d'une des variables explicatives, pour évaluer la variation du bien-être associé à la chasse. Dans le premier exemple, l'écoulement de l'eau polluée réduit les populations d'oiseaux aquatiques de la réserve naturelle, ce qui diminue le nombre d'expéditions sur le site en question et réduit d'autant le bien-être tiré de ce loisir. En particulier, si l'on rapproche la baisse de la pollution par le sélénium de l'accroissement des élevages de gibier d'eau dans la réserve naturelle du Parc de Kesterton, on peut estimer l'accroissement de bien-être correspondant. Dans le second exemple, agriculture et chasse sont en concurrence pour l'utilisation des ressources hydrauliques. La méthode du coût de transport permet de calculer la valeur marginale de l'activité cynégétique par unité d'eau supplémentaire. Ensuite, on compare cette valeur marginale à celle de la même unité dans l'alternative d'un usage agricole. Pour l'une des six réserves, la valeur marginale de l'eau utilisée par les chasseurs était au moins égale à celle de l'eau utilisée en agriculture. L'auteur utilise un modèle zonal de coûts de transport, dont les équations de demande sont estimées par la méthode des moindres carrés et le modèle de Poisson. L'avantage de ce dernier modèle est le traitement approprié de la variable dépendante qui est tronquée à zéro et ne peut prendre que des valeurs entières.

Mots-clés :
méthode des coûts de transport, modèle de Poisson, chasse au gibier d'eau, bien-être et loisirs, agriculture, fourniture d'eau

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Summary *– This paper demonstrates how the Travel Cost Method (TCM) can be used to examine the relationship between agricultural practices and recreation benefits. The first part of the paper provides some basic theoretical descriptions of TCM and some discussion of the actual procedures necessary to successfully conduct a TCM study. Next, two case studies are presented that demonstrate how to link recreation benefits with agricultural activities. These case studies are: 1) an examination of the effects of contaminated irrigation run-off on waterfowl hunting benefits in a wildlife refuge; and 2) a comparison of the value of water in recreational uses versus agricultural uses in California's San Joaquin Valley.*

In both case studies, a sensitivity analysis of the TCM demand equation with respect to one of the explanatory variables is done to derive the change in hunting benefits associated with changes in the variable. The zonal TCM model is used in this paper, with TCM demand equations being estimated both with ordinary least squares and with a Poisson count data model.

Key-words:
travel cost method, Poisson count data model, waterfowl hunting, recreation benefits, agriculture, water deliveries

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THIS paper demonstrates how the Travel Cost Method (TCM) can be used to examine the relationship between agricultural practices and recreation benefits(1). While a few contemporary literature reviews of TCM have mentioned that this technique can be applied to agricultural issues, these reviews have not demonstrated how to perform these applications. Knowledge of how to use this method would be especially useful to researchers interested in measuring the welfare implications of externalities generated by agricultural activities. TCM is particularly useful for valuing recreation, particularly hunting or fishing. One reason is that it is based on observable data, and not hypothetical data, unlike the contingent valuation method (CVM). Another reason is that it can be relatively inexpensive to conduct a TCM study as it sometimes can be done without the need of a specific survey. For example, both of the case studies discussed here use data previously collected by the government for other uses. The downside of TCM is that since it is based on observed data, the range of nonmarket goods that it can be applied to is small relative to CVM.

This paper has two goals. First, this paper will provide some basic theoretical descriptions of TCM and some discussion of the actual procedures necessary to successfully conduct a TCM study. Next, two case studies are presented that demonstrate how to link recreation benefits with agricultural activities. These case studies are: 1) an examination of the effects of selenium-contaminated irrigation run-off on waterfowl hunting benefits in the Kesterson National Wildlife Refuge; and 2) a comparison of the value of water in recreational uses versus agricultural uses in California's San Joaquin Valley. The policy relevant link between the agricultural activity and the TCM model is made in the same way in both case studies. In both case studies, I measure the change in trips, and hence, total consumer surplus due to shifts in an explanatory variable. In the first case study, a change in waterfowl populations changes waterfowl harvest, which, in turn, increases visitation to that site. In the second case study, changes in water deliveries change hunting quality (by increasing the number of visiting birds) at the site, which in turn, increases trips and total hunting benefits at the site. In this case study, given that we can derive from the TCM model the marginal recreational value of an additional unit of water, one can compare this marginal value to the marginal value of an additional unit of water in substitute uses.

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Theoretical and empirical issues for travel cost models

The TCM method uses travel costs to a recreational site as a proxy for the price of the trip and the number of trips as quantity to statistically estimate a demand curve for a site. Once the demand curve is estimated, net willingness to pay can be calculated as the area under the demand curve above actual expenditures. A traditional demand equation, with quantity demanded expressed as a function of the price of the good, cannot be used to model many recreational activities. Because recreation is a nonmarket good, the price for the good is not observed. However, if we assume that people respond to changes in travel cost in the same way they respond to changes in price, travel cost can be used as proxy for the price of the good. See Clawson and Knetsch (1966), Dwyer, Kelly and Bowes (1977), Sorg and Loomis (1985), Ward and Loomis (1986), Sorg (1987), or Ribaudo and Hellerstein (1992) for a discussion of the basic theoretical aspects of TCM approach. This section will concentrate on the mechanics of implementing TCM.

Travel cost demand equations can be estimated using either the individual observation approach (such as direct surveys of recreationists) or zonal averages. In the zonal average case, one essentially estimates a demand curve based on the average distance and participation rates of zones. That is, since the quantity variable is trips per capita, it reflects the representative consumer. Data requirements for zonal TCM can be relatively modest. For example, the dependent variable can be derived from sign-up sheets at the recreational site (many recreational sites such as waterfowl hunting areas and hiking areas require sign-up sheets) as long as the recreationists are required to include their area of origin on the sheet. In spite of some loss in estimation efficiency over the individual observation approach (Brown and Nawas, 1973), this section will concentrate on the zonal approach, due to its lower survey costs. However, to the extent that the true model diverges from the econometric specification, statistically more complex TCM models based on individual data do not necessarily outperform these relatively simple zonal models (Hellerstein, 1994). Fortunately, much of the analysis is the same under either approach.

The zonal TCM demand equation specifies trips per capita from a given zone (such as a county) of origin to a particular site as the dependent variable. Observed visitation rates are assumed to reflect the desired level of consumption given the travel cost facing the recreationist (Dwyer, Kelly and Bowes, 1977). The benefits of a recreational site/activity are reflected in the trips to a site and are generally determined by the cost of traveling to the site, various demographic characteristics, some qualitative aspects of the site, and the existence of substitute or alternative sites or activities(2).

Given the regression estimate of the TCM demand function, the individual net benefits (technically known as consumer surplus) for site *j* for residents from zone *i* is the area under the demand curve above current costs per trip. Total net benefits for the site would be the sum across each origin *i*'s net benefits for site *j*. A frequent goal of a TCM study is to calculate the change in net benefits associated with a change in a qualitative or quantitative attribute of the site, such as acreage at the site open to recreationists(3).

Methodology

The appendix contains technical details on the estimation of the coefficients ($b_1, b_2, ... b_k$, where k is the number of variables in the equation) for the demand function presented in footnote (2). Once the demand coefficients are estimated, net benefits can be calculated utilizing the second stage, or site demand curve approach. Alternatively, to calculate net willingness to pay for a specific zone, the per capita curve can be integrated for each zone of origin (place of residence) over the interval between the current distance and the maximum distance that would force trips to less than one. Site benefits would be the population's weighted sum of each zone's net willingness to pay. Burt and Brewer, (1971) and Menz and Wilton (1983) demonstrate the equivalence of this approach to the "second stage" approach. Finally, Adamowicz *et al.* (1989) provide some equations that can be used to estimate consumer surplus. The second stage site demand curve relates total site visitation to increases in distance (or travel

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(2) The basic population-weighted linear functional form TCM demand equation estimated for site participation is:
$TRIPS_{ij}/POP_i = \beta_0 + \beta_1 TC_{ij} + \beta_2 DEMOG_i + \beta_3 QUALITY_j + \beta_4 SUBS_i + u_i$,(1)
where $TRIPS_{ij}$ is the number of recreational TRIPS from zone i to site j, POP_i is population of zone of origin i, TC_{ij} is the round-trip average travel cost from the recreationist's zone of origin i to site j, $DEMOG_i$ are demographic variables such as average income, age, and years hunted of recreationists in zone i, $QUALITY_j$ can be hunter success, dock availability, or other site characteristics that determine the desirability of site j, $SUBS_i$ is price or availability of substitute recreational sites for origin i, and u_i is a white noise term. Travel time is sometimes included as an explanatory variable but is frequently highly correlated with travel cost.

(3) Weak complementarity allows this calculation to be made. This concept says that the marginal value associated with an increase in the quality of a recreational site is zero if the number of trips to that site is zero, ie, one does not care about a change in quality at a site unless that person visits the site. The notion of weak complementarity (see, eg, Bocksteal and Kling, 1988 for a definition) allows us to determine the value of the nonmarketed amenity. The notion of weak complementarity such that if the commodity TRIPS is a weak complement (as it should be in equation (1) with QUALITY, then the benefits of improvement in QUALITY can be approximately measured from the demand equation for TRIPS.

costs) over and above the existing distance (or cost). Starting with current trips and round trip distance $RTDIST_{ij}$, additional round trip distance is added to $RTDIST_{ij}$ (for example, 10 mile increments) in the demand equation and the new level of estimated $TRIPS_{ij}$ calculated for each origin to each destination (4). Total estimated trips at each successive distance is the sum across observations of total estimated trips for each observation. The area under the generated site demand curve is net WTP (in miles).

The approach to converting the added WTP in miles into dollars follows US Water Resource Council procedures (1979, 1983) of using variable automobile costs obtained from the US Department of Transportation or other sources. For the case studies, the standard vehicle transportation cost per mile represents the variable cost of operating an intermediate-size vehicle. This figure, which was $145 per mile for fuel and service station costs in 1988, was obtained from the 1989 issue of the Hertz Corporation survey of vehicle operating costs. With more than one recreationist per vehicle and assuming each recreationist in the vehicle will pay an equal share of the vehicle operating costs, per-mile costs for individuals will be the per-vehicle-mile operating costs divided by the average number of recreationists (passengers) per vehicle. Of course, the reasonableness of interpreting the travel distance as the price paid to visit the site depends on that site not being part of a multiple destination trip.

The opportunity cost of travel time reflects the deterrent effect that longer drives have on visiting more distant sites, independent of the vehicle operation costs. For example, many higher income people could afford an extra $8.00 of gasoline incurred through driving an additional two hours, but many could not afford the additional time cost in terms of other activities foregone. Empirical evidence supports the contention that time allocated to transportation is viewed by the recreationist as costly (Cesario, 1976; McConnell and Strand, 1981).

The hourly wage is used as a proxy for the opportunity cost of time. This is in part due to work by Cesario (1976), which showed that the opportunity cost of time in commuting studies fell somewhere between one-fourth and one-half the wage rate. Since no information on individuals is available for the data sets used in the case studies presented here, the wage rate will be used as a proxy for opportunity cost of time in all other activities and it is used even if the recreationist would not have been working. The US Water Resources Council Principles and Guidelines (1979 and 1983) suggest that the opportunity cost of time be calculated as one-half of the average wage rate. One should recognize that the issue of what fraction of the wage rate to use is not settled. For instance, Smith *et al.* (1983) argues for using 100 percent of the wage rate.

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(4) The selection criteria for choosing the maximum added travel cost should be one that drives trips arbitrarily close to zero.

Generally, one-third to one-half the wage rate is used. The average wage rate can be calculated as yearly recreationist income (using census data if necessary) divided by 2000 total work hours per recreationist. Next, this new dollar per hour figure is divided by the average travel time (round trip) between the origins and destinations for the study site. The resulting figure, when multiplied by some fraction of the wage rate, is the opportunity cost per mile. Total variable cost per mile per recreationist is this opportunity cost of time plus the recreationist's share of the vehicle operation costs. It is also possible to determine the value of time empirically (Shaw, 1992; McConnell, 1992). However, these models require relatively detailed surveys of the recreationists.

EFFECTS OF AGRICULTURAL ACTIVITIES ON WATERFOWL HUNTING BENEFITS

In this case study, I estimate the economic impact of agricultural activities on wildlife. Specifically, this case study is a TCM application assessing the lost hunting benefits in the Kesterson National Wildlife Refuge in California's San Joaquin Valley due to selenium contaminated agricultural runoff. Using the number of hunting permit applications as the quantity variable, zonal TCM demand curves were estimated and net WTP calculated for waterfowl hunting in California's San Joaquin Valley refuges for the 1987-88 hunting season. In the October 1987 through January 1988 hunting season, 27,603 hunters went to these seven refuges.

For this study, applications (hunting permits) data were used as the quantity variable as trip data was not available. However, this substitution does have the positive characteristic that the number of hunting applications for site *j* filed by hunters from origin *i* is the unconstrained demand for the site. Applications reflect the consumption that waterfowl hunters desire at current permit and travel prices.

The estimated model, which includes six other San Joaquin Valley refuges, is(5):

$$\begin{array}{llll} \ln(\mathrm{APPLICATIONS}_{ij}/\mathrm{POP}_i) = & -24.277- & 1.406[\ln(\mathrm{TWOWYDIST}_{ij})] & \\ \{\text{t-statistics}\}: & (-7.77) & (-15.25) & (2) \\ +0.235[\ln(\mathrm{HVST}_j)] & +0.733[\ln(\mathrm{AVINCOME}_i)] & +1.301[\ln(\mathrm{WATER}_j)], & \\ (2.53) & (2.33) & (9.96) & \end{array}$$

where:
POP_i=population of county of residence i;

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(5) Because this analysis was done before count data models were used for TCM, ordinary least squares was used as the regression model. Also, note that this demand function applies only to counties that demanded at least one application.

TWOWAYDIST=two-way trip distance from the hunter's resident county *i* to refuge *j*. This variable is the price (in terms of distance travelled) of visiting the refuge;
HVST=average of the monthly total waterfowl harvest for all hunters in the previous season, such as in the 1986 season, in refuge *j*;
AVINCOME=average income in county *i*;
WATER=total water supplied (acre-feet) to refuge *j*'s wetlands during the hunting season.
(This variable is a proxy for the amount of waterfowl habitat at a refuge);
R-squared = 0.607; F-Statistic = 102.23; and observations = 270.

The R-squared is quite high for a cross sectional TCM regression. In addition, all the coefficients are of the expected sign, and all are significant at the 5 percent level or higher. Note that inclusion of all six sites in the regression allows us to include the $HVST_j$ and $WATER_j$ variables, which only vary across sites in this cross sectional model.

Table 1.
Net benefits per hunter-day and total consumer surplus for the 1987-88 season, in selected San Joaquin Valley wildlife areas

Refuge	Average net benefits per hunter-day	Hunter days per year	Total Net benefits	Total Hunters
	Dollars	*Number*	*Dollars*	*Number*
Kesterson NWR	37.19	3,900	145,000	1,803
San Luis NWR	51.11	9,000	460,000	3,418
Merced NWR	43.46	1,700	73,880	710
Volta WA	60.01	3,500	210,000	4,067
Los Banos WA	62.98	3,500	220,400	3,354
Mendota WA	63.74	31,723	2,022,000	12,055
Kern NWR	69.36	1,300	90,170	2,196
Average	55.41	54,600	3,222,000	27,603

NWR = National Wildlife Area
WA = Wildlife Area

Given equation (2), net benefits are estimated using the second-stage approach discussed earlier. Table 1 presents the average net benefits per hunter day and the total net benefits for the San Joaquin National Wildlife Refuges and Wildlife Areas. Net benefits per hunter-day is equivalent to net benefits per application as an application is only valid for one day. Since the demand equation (2) underestimates applications, the benefit estimates err on the conservative side(6). However, because of the double-log formulation, this underprediction does not affect net

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(6) Since OLS regressions run through the mean of the dependent variable, the OLS equation (2) correctly predicts mean (and total) ln(APPLICATIONS/POP), which is the dependent variable in that regression. However, predicted $APPLICATIONS_{ij}$, is exp (predicted $\ln(APPLICATIONS_{ij}/POP_i)$)*POP_i. Once this conversion is done and summed across observations, there is no econometric reason why total predicted $APPLICATIONS_{ij}$ should equal total estimated $APPLICATIONS_{ij}$.

benefits per trip. Column 2 is actual hunter days per year. The third column is the product of columns one and two.

Because the estimated model includes harvest, it can be used to estimate how waterfowl hunting benefits alter with changes in harvest induced by contamination of the refuge water supply.

In the San Joaquin Valley refuges, the primary harm to wildlife resulting from agricultural drainage is due to the high selenium concentration in much of the drainage water. Although selenium is a necessary nutrient for life, high concentrations can cause both deformities and death. Selenium is particularly harmful to waterfowl embryos. The majority of refuges listed in table 1 receive little agricultural drainage, and, correspondingly, have nonlethal levels of selenium. However, the concentration of selenium at Kesterson, which was a major receptor of agricultural drainage, was especially high and lethal to a large percentage of the waterfowl population that had bred there.

Ohlendorf (1989) estimated the frequency of embryotoxicity (dead or deformed embryos or chicks) attributable to selenium in nesting aquatic birds at the Kesterson refuge during 1983-85. In 1983 (the only year for which coot data is available), 64.4 percent of coot nests had one or more dead or deformed embryos or chicks. For 1983-85, an average of 34.9 percent of duck nests had one or more dead or deformed embryos or chicks.

The reduction in these death and deformity figures are used to determine the increase in waterfowl hunting benefits at Kesterson associated with a reduction in selenium concentrations to nonlethal levels. To do this, the 1986 waterfowl harvest data used to estimate equation (2) was separated into its duck, geese, and coot components, which were 94.4, 2.0, and 3.6 percent of total 1986 harvest, respectively, for the San Joaquin Valley refuges (California Department of Fish and Game, 1986 Waterfowl Hunting Season Report). The percent of harvested ducks and coots bred in the San Joaquin Valley is estimated using Department of Fish and Game estimated 1989 breeding population data for the San Joaquin Valley refuges(7). The figures suggest that 11.5 percent of the total winter duck population and 3.9 percent of the total winter coot population are bred there. For a lack of better information, it is reasonable to assume that of the ducks and coots harvested in Kesterson, 11.5 percent and 3.9 percent, respectively, were bred there.

Using the embryotoxicity figures listed above, the increase in the number of harvested ducks and coots bred at Kesterson due to a decrease in the selenium levels to nonlethal concentrations is calculated. Without factoring the possibility of compensatory mortality due to a lack of in-

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(7) Data for 1986 were not used as no coot data was collected that year. Also note that no geese breed there.

formation on its magnitude, it is assumed that 64.4 percent of dead or deformed coot embryos or chicks and 34.9 percent of dead or deformed duck embryos or chicks would have survived at nonlethal selenium concentrations. For want of more detailed embryo or chick mortality data, the dead or deformity percentages, which are the percentages of all nests with one or more dead or deformed embryos or chicks, are assumed to be the total death or deformity percentages for a clutch of eggs. This plus the preceding assumption may lead to a liberal estimate of the increase in native waterfowl population due to a decrease to nonlethal levels of the selenium concentration. On the other hand, no adjustment is made for the possible decrease in reproductive ability of waterfowl that inhabit the refuge in winter but breed somewhere else, as no data exists on this topic.

Using the figures cited above, of the 509 waterfowl harvested in Kesterson in 1986, 51 ducks and 1 coot were estimated to be bred there. With selenium reduced to a nonlethal concentration, 538 waterfowl (a 5.7 percent increase) would have been harvested there. Substituting this harvest figure into equation (2), yields a 1.4 percent increase in Kesterson hunting applications. This percentage increase translates into an increase of 55 hunter days in the sample expansion of Kesterson hunter visitation figures from table 1. With this small increase, the potentially negative impact of crowding from increased visitation on applications should not be of major concern. With this increase in hunter visitation, the total net benefits increases by $2.030. Assuming a 100-year horizon for this increased surplus and an 8 percent discount rate used by Federal water resources agencies, the present value of this increase in net benefits is $25.400.

An increase in the total economic benefits of bird viewing at Kesterson resulting from a decrease in selenium concentration to nonlethal levels should be added to this figure. However, a lack of Kesterson bird viewing data makes this addition difficult at this time. However, the values estimated do give a lower bound to the net benefits losses at the site.

ESTIMATION OF THE MARGINAL VALUE OF AN ACRE-FOOT OF WATER IN RECREATION VERSUS AGRICULTURE

This case study makes a comparison of the marginal value of an acre-foot of water in recreational use versus agricultural use, thus aiding the policymaker in the best use of additional units of the resource. The specific application is water deliveries to San Joaquin Valley National Wildlife Refuges.

Data sources

This case study uses a more recent data set (Cooper, 1990) than the one used in the previous case study. This data set consists of the whole population of hunters to the six San Joaquin Valley National Wildlife Refuges for the 1989-1990 hunting season. Waterfowl hunting trip data for San Joaquin Valley refuges were obtained from on-site sign-up sheets hunters are required to sign before they enter the hunting area. Hunters are required to list their license number and home zip code. The sheets include both reservation holders and those hunters that show up for the "sweat line" (hunters without reservations who arrive at the refuge and are granted the remaining available slots in the hunting area).

Hunters are aggregated by county of origin. To avoid truncation bias, all counties in California where no hunters originated from were retained in the survey. The availability of this data, which was collected for administrative purposes, shows how it is possible to do TCM studies without funding an original survey.

The qualitative variable of key interest in this case study is the level of water deliveries (H20DEL, measured in acre-feet). Increasing water deliveries to a site affects recreational demand by increasing the waterfowl population, and hence harvesting opportunities, at the site, and also by increasing the aesthetic quality of the refuge. Unlike many possible site characteristics that are not realistically under societal control, such as the amount of snow cover, water delivery to the wildlife refuges is largely controllable. Hence, an analysis of the effects of changing this variable is policy relevant.

The distance figures from the counties to the refuges were determined using a California Department of Transportation computer program (CALTRANS). CALTRANS also supplied the household income and county population figures. Because many of the Merced County refuges are centered within a close proximity of each other, that county was divided into smaller regions. This segmentation increases the precision of the distance variable.

Statistical results

Two regression techniques – ordinary least squares (OLS) and the Poisson count model – were used on the data to estimate the TCM demand equation coefficients. For reasons discussed in the appendix, the Poisson model is preferred over the OLS model. However, because OLS is the traditional regression technique, OLS coefficient estimates are still useful for comparative purposes. The regression results for these two models are found in table 2. In table 2, all coefficients are of the expected sign and are statistically significant(8). All the OLS coefficients were larger than the Poisson coefficients, with the greatest difference being that for INCOME and the smallest that for H20DEL.

Model Application

An application of the above model that could be valuable in policy-making decisions is to calculate the marginal value of an acre-foot of water in recreational uses. Much pressure has been put on the Bureau of Reclamation to allocate more water to National Wildlife Refuges. The economically optimal water distribution plan would be one that allocates water to each use to the point where the marginal value of the water in each use is equal.

Table 2. **OLS and Poisson coefficient estimates for the TCM demand equation**

Variable	Log-Linear OLS	PML Poisson
Constant	-16.2610	-8.8154
	(-10.8342)(a)	(-59.48)
RTDIST	-0.01496	-0.00887123
	(-11.28)	(-28.39)
INC	0.000109	4.2163E-06
	(3.2789)	(1.573)
PSBAG	36.1707	10.51211
	(4.0791)	(3.94)
H20DEL	0.000145	0.0001257
	(2.58)	(18.04)
α (b)		26437
η^2 (c)	0.268	0.516

The variables are:

RTDIST is round trip travel distance from county *i* to refuge *j*.

H20DEL is water deliveries to refuge *j*.

INCOME is average income in county *i*.

PSBAG is the price, in terms of round trip distance, of the most popular alternative refuge to refuge *j* for residents of origin *i* divided by the bag at that site

Total observations = 396

(a) Coefficient divided by its standard error in parentheses

(b) The standard error for α is not available with PML estimation

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(8) Distance to substitute sites can be included in the regression as a proxy for the price of substitute hunting activities. However, to reduce the level of multicollinearity between RTDIST and the distance to substitute sites and to add information on the relative quality of each of the substitutes, PSBAG is created by dividing distance to the substitute site is by the total bag at the alternative. Economic theory suggests that the coefficient on this variable should have a positive sign. This variable also includes NWR's in the Sacramento Valley (Cooper, 1990). Because the refuges tend to lie at similar distances from many of the areas of origin, including the prices of all eleven substitutes as individual variables would generate too much multicollinearity in the regression, thereby lowering the statistical efficiency of the results.

(c) $\eta^2 = 1 - RSS/TSS$, where RSS is explained sum of squares and TSS is total sum of squares. For OLS (with a constant term), η^2 equals ESS/TSS, though this is not necessarily the case for nonlinear models (Peterson and Stynes, 1986)

Table 3. **Marginal value of an additional acre-foot of water in waterfowl hunting (change in total net benefits with a one acre-foot increase in water deliveries)***

	PML Poisson Regression			OLS Regression		
Refuge	Lower	Upper	Average *(Dollars)*	Lower	Upper	Average
Kesterson	2.99	3.71	3.34	0.91	3.84	2.30
Los Banos	7.70	9.57	8.62	2.35	9.92	5.94
Mendota	18.24	22.66	20.40	5.55	23.48	14.05
San Luis	5.75	7.15	6.43	1.75	7.40	4.43
Volta	6.88	8.55	7.70	2.10	8.86	5.30
Merced	0.83	1.03	0.93	0.25	1.07	0.64

*Confidence intervals based on 1000 repetitions.

Table 3 presents the marginal values calculated using both the OLS and the Poisson results from table 2. The marginal values are defined as the changes in total net benefits to waterfowl hunters of an additional acre-foot (over the current delivery levels) of water delivered to each refuge. The 90 percent confidence intervals were constructed using the Krinsky and Robb approach (Cooper, 1994) with 1000 draws. For the Poisson and OLS models, the average of the draws ranged from $0.93 and $0.64, respectively, for Merced, the least visited refuge. For Mendota, the refuge with the greatest visitation, the Poisson and OLS results were $20.40 and $14.05, respectively. These marginal values form a base on the marginal values to recreation as they only include waterfowl hunting.

Table 4. **Marginal value of an additional acre-foot of water in waterfowl hunting (change in total net benefits with a one acre-foot increase in water deliveries) using uncalibrated PML Poisson regression**

	Marginal Value		
Refuge	Lower	Upper *(Dollars)*	Average
Kesterson	1.95	2.24	2.09
Los Banos	9.22	12.66	10.87
Mendota	12.80	20.24	15.61
San Luis	6.49	8.18	7.32
Volta	4.46	5.24	4.85
Merced	6.46	8.28	7.35

Note that unlike in table 3, for the calculation of the net benefits, the demand curve is not shifted such that it passes through actual price and quantity.

For comparative purposes, Table 4 presents the uncalibrated results (the demand equation is not adjusted such that base estimated trips per site are equal to actual trips per site). Because the demand curve passes through average price and quantity in the uncalibrated equation, the difference across sites in the WTP point estimates is lower for the uncalibrated results than for calibrated results. Since waterfowl hunting makes up only 14 to 19 percent of the total recreational use of refuges, depending on the relative value of water in waterfowl hunting versus fishing, the marginal recreational values of water in table 3 could be several times higher (Calliga, 1982; Creel and Loomis, 1991). However, because it provides important information in that table 3 gives the lower bounds to the marginal recreational value of water.

Several researchers have estimated the marginal value of an acre-foot of water to California agriculture (see Gibbons, 1986, for a literature review). For this paper, the Economic Research Service's US Agricultural Resource Model (Konyar and McCormick, 1990) was run specifically for California. This model is a partial equilibrium, comparative statics programming model(9). Running the model expressly for California yielded a shadow price (using 1987 crop prices) of $13.37 for an acre-foot of irrigation water. The true shadow price, or marginal value, for the San Joaquin Valley would differ from this value depending on the extent to which the water bound for the San Joaquin Valley can be transported to other parts of the state and on how different the crop mix for the San Joaquin Valley is from the crop mix representative of the state. This $13.37 value is greater than the marginal recreational value for all sites except Mendota. Hence, additional water for waterfowl hunting at Mendota is competitive with agricultural use. When the presently unquantified benefits to nonconsumptive wildlife use are added in, the benefits of increases in water deliveries to some of the other refuges in the San Joaquin Valley may be greater than or equal to the foregone marginal value of agricultural water in the San Joaquin Valley, with the Merced National Wildlife Refuge being a possible exception in table 3 or Kesterson in table 4.

At a macro level, economic theory suggests that water should be allocated between agriculture and the national wildlife refuges such that the marginal value of water is equal between the two uses. At a less macro level, if the goal of the Bureau of Reclamation would be to allocate water to the sites to maximize the total recreational benefits provided by the national wildlife refuges, it should reallocate the water deliveries between the refuges such that the marginal recreational values of an acre-foot of water are equated across the refuges. This is not currently

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(9) As described by Konyar and McCormick, "*The model contains 23 regions, the 17 Western states and the 6 Eastern USDA production regions. The crops included in the model are barley, corn, cotton, oats, rice, sorghum, wheat, hay, and soybeans. The endogenous decision variables are; land to allocate to crops at the regional level, participation in the government commodity programs, and irrigation or dryland cultivation. Each activity has a positively sloping supply curve at the regional level...The objective function is the area between linear demand and supply curves. Maximizing the objective function is tantamount to solving the competitive equilibrium problem.*"

the case for majority of the sites, based on the Poisson confidence intervals. For example, the marginal value estimates in table 3 suggest that too much water is being delivered to the Merced and Kesterson refuges and too little to Mendota.

CONCLUSION

Through two case studies, this paper has demonstrated that TCM can be used to link recreational activities to agricultural activities. In both case studies, a sensitivity analysis of the TCM demand equation with respect to one of the explanatory variables is done to derive the change in hunting benefits associated with changes in the variable. In the first case study, contaminated irrigation run-off decreases waterfowl populations in a wildlife refuge, which in turn decreases hunting trips, and hence, decreases total hunting benefits associated with the site. Specifically, by linking reductions in selenium contamination to increases in waterfowl breeding populations at Kesterson National Wildlife Refuge, an estimate of added benefits to waterfowl hunters is computed for reductions in contamination. More precise estimates of the economic effects await better biological data for on-site and off-site contamination effects on migratory birds. In the second case study, farming and waterfowl hunting are competing uses for the available water. The TCM model in this case was used to develop a marginal hunting value for an additional unit of water. This marginal value was then compared to the marginal value of that same unit of water to the substitute agriculture use. For one of the six refuges, the marginal value of water in waterfowl hunting was at least as great as the marginal value of water in agriculture. In order to make more complete comparisons of the economic benefits of water use, further research is needed to quantify the marginal value of water to other popular recreational uses of refuges such as bird watching and fishing.

Although TCM is the obvious modelling choice in cases where changes in on-site recreational demand occurs, it does have some limitations, however. For instance, TCM requires observed data, in particular, it requires recreational participation data. Furthermore, TCM is only practical for application to recreational sites that are the primary destination of a trip. Since most agricultural issues do not involve recreational opportunities, these two requirements limit TCM's role in assessing the economic impacts of agricultural activities. The other major nonmarket valuation technique, the contingent valuation method (CVM), is not subject to these limitations. However, even though TCM can only give the benefits associated with on-site use of the wildlife refuges, it still usefully links site visitation and agriculturally related impacts at the site by providing the lower bound for the nonmarket values of these sites.

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APPENDIX

Additional Details on the Econometric Specification Travel Cost Models

Although recreational demand models were traditionally estimated using estimators such as ordinary least squares (OLS), count data regression models such as the Poisson or negative binomial are rapidly supplanting or replacing the use of these older techniques for several reasons (Hellerstein, 1991 ; Creel and Loomis, 1990). Namely, in recreational demand models, trips are censored at zero. In other words, it is not possible to take negative amounts of trips. Also, trips are not drawn from a continuous distribution – one cannot take a fraction of a trip. Unfortunately, OLS does not account for the censoring and the integer nature of the dependent variable and may produce biased, and almost certainly, inefficient estimates. Count data models address both the issue of censoring and the integer nature of trips. In addition, some behavioral justifications have been made for the use of count data models (Hellerstein, 1991). But whether or not one agrees with these various behavioral justifications for the use of count data models, these models merit strong consideration for TCM from purely an empirical standpoint(10).

The Poisson and the negative binomial are the most common distributions used in the count data models, both of which assume a distribution over Prob(TRIPS = trips; trips = 0,1,2,...). The single parameter Poisson distribution has a rather strict assumption that the mean, E(TRIPS), and variance, σ^2(TRIPS), of the distribution are equal. The two parameter negative binomial relaxes this assumption and allows the variance to vary. By doing this, the negative binomial can control for overdispersion of the dependent variable.

The most common functional form for the Poisson parameter and the negative binomial mean is

$$\lambda = E(TRIPS) = POP * \exp(\beta_0 + \beta_1 TC + \beta_2 DEMOG + \beta_3 QUALITY + \beta_4 SUBS), \qquad (3)$$

where POP, TC, DEMOG, QUALITY, and SUBS are the means of the variables that are defined in footnote (2), and E(TRIPS) is estimated mean trips(11). The functional form in equation (3) eliminates the possibility of

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(10) Other possible indirect, revealed preference models include discrete choice models, such as the random utility model (Parsons and Kealy, 1992). Like the count data models, this model also accounts for censored data. However, this method is quite expensive compared to the zonal approach as it requires purpose built surveys.

(11) Note that equation (2) is estimated with POP weighing the righthand side, instead of using TRIPS/POP as the dependent variable, as is the case for the OLS model.

a negative λ. Because aggregate data for a zone of origin is used in the zonal TCM data sets, the populations for the zones of origin must be factored into the model. Using population as a multiplicative weight is suggested by the empirical properties of count data models (Hellerstein, 1991). Given the parameter estimates, the expected number of trips from each county of origin i to each site j is $E(TRIPS_{ij}) = POP_i * \exp(\beta_0 + \beta_1 TC_{ij} + \beta_2 DEMOG_i + \beta_3 QUALITY_j + \beta_4 SUBS_i)$. Among the useful properties of the Poisson and negative binomial are that zero trip values are allowed (with OLS, the log of $TRIPS_{ij} / POP_i$ is frequently the dependent variable) and that, if a constant is included, the sum of predicted trips across all observations is equal to total actual trips.

The need to acknowledge nonparticipants in TCM should be stressed. To exclude zero value trips (in the aggregate context, all zones of origin do not necessarily display a positive level of trips to all sites) is to exclude important data about nonparticipation from the data set, thereby possibly biasing the results. An advantage of the zonal approach compared to surveys of individuals is that it is simple to include nonparticipants in the data set. If the data sets contain all the recreationists who traveled to the study sites during a one year period or during the whole season (such as the ones used for the case studies), the true level of participation, and thus, nonparticipation is known. Truncation bias is avoided by including areas of origin with zero trips in the data set. Since taking the log of the trip variable is avoided with the count data models, unlike with the semi-log OLS models, the count data models easily accept zero trips.

However, even with its drawbacks, an OLS regression is useful for comparative purposes. In the TCM literature, the predominant functional forms chosen for the traditional OLS recreation demand functions are the linear, linear-log, log-linear, and the log-log. The log-linear and the log-log functional forms possess several desirable traits missing from the other commonly used functional forms. Past research has shown that taking the natural log of trips per capita minimizes two problems that arise with a linear model. First, the log of trips per capita eliminates the possibility of predicting negative trips per capita, which can occur with the other functional forms. Second, heteroskedasticity associated with zones of different population sizes is minimized using the log of the dependent variable (Strong, 1983; Vaugh *et al.*,1982). If the log-linear functional form with $\ln(TRIP_{ij}/POP_i)$ as the dependent variable is selected for the OLS regression, one can compare the OLS coefficient estimates to the count data coefficients(12). Of course, a small constant

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(12) Of course, the equivalent functional form $TRIPS_{ij} = POP_i * \exp(X_i * \alpha) * \varepsilon_i$ could be estimated directly using nonlinear least squares (NLS), thereby avoiding the need to add a constant term to $TRIPS_{ij}$ in the log-linear model. However, the estimation results with NLS tend to be quite sensitive to the starting values chosen for the coefficients.

(such as 0.00001) needs to be added to $TRIP_{ij}$ to allow the inclusion of zero values in the OLS regression.

Other Issues in Benefit Estimation Using TCM

Finally, opinions differ as to whether the estimated demand curve should be forced to pass through actual price and quantity in the net benefits estimation stage. As a base to estimating the site benefits, the second stage demand equation can be calibrated so that the total systematic portion of the demand function runs through actual price (round-trip distance) and observed quantity for each site. The author's opinion is that in order to produce an unbiased estimate of total net benefits per site, it is necessary to have an unbiased estimate of total trips per site. The adjustment factor can be (total estimated base $TRIPS_j$) / (actual $TRIPS_j$), $j = 1, ..., J$ sites. This approach consistent in philosophy with the Gum and Martin (1975) procedure of shifting the demand curve through the actual price and quantity. If one assumes, as do Bockstael and Strand (1987), that the TCM equation is subject to omitted variables (that are uncorrelated with the included variables), which is the most plausible scenario, then actual quantity and price should be used in the surplus estimation function. For a dissenting view, see McKean and Revier (1990). For semi-log or double-log demand function specifications, multiplying the estimated demand function by this adjustment does not affect the CS per trip value. When calculating the area under the semi-log second stage demand function, a change in any of the exogenous variables except price will cause total net benefits and estimated trips to move in the same direction and in the same proportion, (an increase in site quality is expressed as more trips, with net benefits per trip constant with the semi-log form). Hence, an unbiased estimate of total net benefits can be made by multiplying actual trips by the net benefits per trip.