Joint Estimation of Revealed and Stated Preference Data: An Application to Recreational Red Snapper Valuation

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This study extends the joint estimation of revealed and stated preference data literature by accounting for truncation in the revealed preference data. The analytical model and estimation procedure are used to estimate the value of recreational red snapper fishing in the Gulf of Mexico. This recreational red snapper valuation is decomposed into its direct and indirect components. As expected, the value of recreational red snapper fishing using the joint revealed-stated preference model proposed in this analysis is bracketed on the upper limit by the value obtained using the contingent valuation method and on the lower limit by the travel cost method. The results also indicate that the joint model improves the precision of estimated recreational red snapper valuation.

Key Words: bivariate normal distribution, contingent valuation, recreation demand, travel cost

During the last decade researchers began to jointly estimate revealed (recreational trip demand) and stated (dichotomous choice contingent valuation) data to estimate the value of recreational resources.[1] Building on Cameron (1992), a number of papers (e.g., Loomis, 1996; Huang, Haab, and Whitehead, 1998; and Niklitschek and Leon, 1996) have refined and generalized the econometric methods for jointly estimating recreation demand models using data sets containing both travel cost and contingent valuation data. Using simulated contingent valuation and travel cost data, Kling (1997) found that joint estimation can substantially improve the precision of estimated parameters and reduce bias in the willingness-to-pay (WTP) estimates, especially when the sample size is small.

In each of the studies cited above, the econometric model was based on a bivariate normal distribution with a nonzero correlation coefficient. One critical difference among the estimated models is how the error term in the recreation demand function is specified. For example, Cameron (1992); Loomis (1996); and Huang, Haab, and Whitehead (1998) specified the error term for the recreation demand function as a continuous standard normal distribution. Alternatively, Niklitschek and Leon (1996) specified the error term for the recreation demand function as a censored standard normal distribution.

The current study contributes to the recreation demand literature in three ways. First, we derive the appropriate estimation procedure for a joint contingent valuation method-travel cost method (CVM-TCM) model in which travel cost data are truncated, i.e., all observations take at least one trip. This contribution is important because most survey data pertaining to sporting anglers are obtained from intercept surveys or from anglers' log books; thus,

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[1] In this study, we focus on the joint estimation of recreational trips and dichotomous choice contingent valuation responses. Alternatively, earlier studies by Loomis et al. (1996), and Englin and Cameron (1996) focus on combining revealed recreation trips (actual trips) with stated trips (intended trips) for a given quality change.

the number of fishing trips for each observation is likely to be nonzero. For such data, the assumption that error structure is distributed censored at zero is clearly inappropriate. The procedure developed here is therefore a more suitable approach for many if not most recreational fishing data sets. Moreover, as demonstrated by Kling (1997), the use of the joint model improves the efficiency of the estimated parameters, leading to more precise estimates of recreational valuation of red snapper. Furthermore, to our knowledge, this is the first investigation to combine the CVM with the truncated TCM.

This study's second contribution is the application of the methodology described above to estimate the value of the recreational red snapper fishery in the Gulf of Mexico and to establish the importance of catch rates in determining welfare estimates. Finally, results from this study are used to evaluate the effect of bag limits on the Gulf's recreational red snapper fishery.

Our emphasis on the Gulf of Mexico red snapper recreational fishery is justified by the importance of this fishery and its precarious state. The commercial red snapper fishery is the fourth most valuable fishery in the Gulf of Mexico and represents more than 95% of total U.S. red snapper landings (Brown, Bohnsack, and Harper, 1989). Although there is limited information available on the value of the red snapper recreational fishery, harvests by recreational anglers are roughly equivalent to those of the commercial sector. Further, because the resource (red snapper fish) is pooled between the commercial and recreational fisheries, regulations on one fishery will affect the other. As a result of severe overfishing from direct harvesting of adult red snapper by the commercial and recreational fisheries and from indirect harvesting (bycatch) of juvenile red snapper by the shrimp fishery, the stocks are estimated to have declined 90% since the 1970s (Goodyear and Phares, 1990).

In an effort to rebuild declining red snapper stocks, the National Marine Fisheries Service (NMFS) and the Gulf of Mexico Fishery Management Council have undertaken a series of regulatory efforts aimed at restricting the harvest of red snapper by the commercial, recreational red snapper, and shrimp fisheries. The regulatory instruments consist of: (*a*) total allowable catch (TAC) quota on the commercial and recreational red snapper sectors, (*b*) bag limits for the recreational red snapper sector, (*c*) minimum size limits on the commercial and recreational red snapper sectors, and (*d*) bycatch reduction device (BRD) on shrimp trawls.

The bag limit is the instrument directly driving this research. This regulation has become tighter over time, dropping from a bag limit of seven to a limit of four fish per angler per recreational trip. Understanding the relationship between catch rates and the recreation demand will provide fishery decision makers with important information for benefit and cost analysis. Despite the importance of this fishery and the need to understand the economic impact of catch limitations, the recreational fishing demand literature that focuses on the red snapper fishery is limited.

Table 1 highlights the place of the current study relative to other studies within the recreational demand literature by summarizing the various points of subject area focus. As shown in the table, only the works by Gillig, Ozuna, and Griffin (2000) and Haab, Whitehead, and McConnell (2000) have investigated the economic values directly associated with catch rates specifically for red snapper. However, these works employ either the travel cost model (Gillig, Ozuna, and Griffin) or the random utility model (Haab, Whitehead, and McConnell) to estimate the economic values of the recreational red snapper fishery.

Based on our review of literature, this analysis is the first to combine a nonmarket valuation model (TCM and CVM) in the recreational red snapper fishing demand. By applying the joint truncated TCM and CVM to the Gulf of Mexico recreational red snapper fishery, this study makes an important contribution to the econometric literature while at the same time providing improved estimates of the red snapper recreational fishing demand, which is needed for policy analysis.

The current study is linked to the earlier work of Gillig, Ozuna, and Griffin (2000) in that the same data set is used to evaluate the same recreational red snapper economic values. However, this study is distinct in four key respects. First, while Gillig, Ozuna, and Griffin emphasize the decomposition of the travel cost model using the Tobit estimation procedure, this study emphasizes the use of a joint contingent valuation and truncated travel cost model. Second, here we highlight the usefulness of joint CVM and TCM, focusing on efficiency gains that can be achieved with much smaller and simpler data sets. Third, this study uses a compensating variation (exact welfare measures) which is derived directly from the red snapper anglers, while Gillig, Ozuna, and Griffin use an expected change in consumer surplus (approximation of welfare measures) derived from the reef fish anglers, including both

Table 1. Summary of Related Recreational Fishing Demand Studies

Description	Current Study	Greene, Moss, and Thunberg (1994)	Greene, Moss, and Spreen (1997)	Milon et al. (1994)	Bockstael et al. (1990)	Gillig, Ozuna, and Griffin (2000)	Haab, Whitehead, and McConnell (2000)	Cameron (1992)	Niklitschek and Leon (1996)	Huang, Haab, and Whitehead (1998)
Methodology:										
Contingent Valuation	T			T	T			T	T	T
Travel Cost	T	T				T		T	T	T
Random Utility			T				T			
Joint Model	T							T	T	T
Model Specification:										
Non-truncation		T	T		T	T		T	T	T
Truncation	T									
Application:										
Nonrecreational Fishing Demand									T	T
Recreational Fishing Demand:	T	T	T	T	T	T	T	T		
< red snapper species	T					T	T			
< reef fish		T								
< other fish			T	T	T		T	T		
Estimated Economic Values:										
< focus on catch rates as fishing quality	T	T	T	T		T	T			
< focus on water quality, site amenities, etc.							T	T	T	T
Recreational Fishery Policy Analysis	T			T			T			

red snapper and non-red snapper anglers. Fourth, our estimate of the cost to anglers of bag limits is more precise, as indicated by the coefficients of variation—providing improved information for decision makers evaluating fishery policies.

Theoretical Framework

Following the standard derivation of demand for environmental quality (Larson, 1991), we assume recreational anglers maximize their utility function $U\{f(x, z, q), q\}$ subject to a budget constraint, $xp + z \leq m$, where x is the number of recreational fishing trips to a recreational site, z is a composite commodity with price normalized to unity, q is a catch rate representing recreational fishing quality, p is travel expenditures used as a proxy for recreational fishing prices, and m is income.[2] This utility specification implies the catch rate both directly and indirectly affects an angler's utility. Directly, the catch rate affects anglers' utility as an argument of $U(\cdot)$. Indirectly, the catch rate affects anglers' utility through the number of recreational fishing trips.

Suppose that $x^* = x(p, q, m)$ and $z^* = z(p, q, m)$ represent the set of Marshallian demands for the recreational fishing trip and the other composite commodity, which are a result of an angler maximizing utility subject to a budget constraint. By substituting these Marshallian demands into the utility function, the indirect utility function, $\upsilon(\cdot)$—which gives the maximum utility achievable at a given price (p) and income (m)—can be expressed as:

$$(1) \qquad \upsilon(\Lambda(p, q, m), q) = U(x^*(p, q, m), z^*(p, q, m), q).$$

Applying Roy's Identity (Varian, 1992; Larson, 1991), we obtain:

$$x^*(p, q, m) = -\frac{\partial\upsilon(p, q, m)/\partial p}{\partial\upsilon(p, q, m)/\partial m} = \frac{dm}{dp}.$$

[2] Substitute recreational sites are not considered in the model since it is developed for a broad geographic area—the Gulf of Mexico. According to Bockstael, McConnell, and Strand (1989), a recreational fishing trip from any site (e.g., Florida, Alabama, Louisiana, Mississippi, or Texas) of a broad geographical area such as the Gulf of Mexico can be treated as a homogeneous trip.

The recreational demand function, $x^*(p, q, m)$, is assumed to take the form:

$$x = \alpha + \beta p + \gamma m + \delta q = \frac{dm}{dp}, \quad x > 0,$$

where α, β, γ, and δ are, respectively, the intercept term and the coefficients on price, income, and catch rate. Solving this differential equation for m yields:

$$\text{(2)} \qquad E\big(p, q, \theta(q, u)\big) = \theta(q, u)\exp(\gamma p) - \left(\frac{1}{\gamma}\right)\left(\alpha + \beta p + \delta q + \frac{\beta}{\gamma}\right),$$

where $\theta(q, u)$ is the constant of integration, which normally depends on q, and $E(\cdot)$ is the expenditure function. Equation (2) is well defined as long as $0 \le x \le -\beta/\gamma$ (Larson, 1991). Note that this constant of integration obtained still depends on nonprice parameters (fishing quality). To solve this problem, we adapt a weak complementarity assumption used in Mäler (1974); Bockstael and Kling (1988); and Larson (1991). Specifically, we assume fishing quality is a weak complement to recreational trips, so that a change in fishing quality does not matter to anglers who do not take a trip.

To solve for the choke price, where demand is zero, we find the price ($\hat{p}$) such that the Hicksian demand is equal to zero. The Hicksian demand is obtained by taking a derivative over the expenditure function, equation (2), with respect to price:

$$\gamma\theta(q, u)\exp(\gamma\hat{p}) - \frac{\beta}{\gamma} = 0,$$

$$\ln\big[\gamma\theta(q, u)\big] + \gamma\hat{p} = \ln\left[\frac{\beta}{\gamma}\right],$$

and the choke price is

$$\hat{p} = \left(\frac{1}{\gamma}\right)\ln\left(\frac{\beta}{\gamma^2\theta(q, u)}\right).$$

Evaluating equation (2) at the choke price ($\hat{p}$) and simplifying, we have

$$E\big(p, q, \theta(q, u), e\big) = -\left(\frac{\alpha + \delta q}{\gamma}\right) - \left(\frac{\beta}{\gamma^2}\right)\ln\left(\frac{\beta}{\gamma^2\theta(q, u)}\right).$$

The weak complementarity assumption implies:

$$dE\big(\hat{p}, q, \theta(q, u)\big) = \frac{\partial E\big(p, q, \theta(q, u), e\big)}{\partial q}\, dq = 0,$$

which yields

$$\left[\frac{1}{\theta(q, u)}\,\frac{\partial\theta(q, u)}{\partial q}\right] dq = \frac{\delta}{\gamma}\,\frac{\gamma^2}{\beta}\, dq.$$

Both sides can then be integrated over q and simplified to obtain:

$$\text{(3)} \qquad \theta(q, u) = \zeta\exp\left(\frac{\gamma\delta}{\beta}\, q\right),$$

where ζ is a constant of integration that is a non-decreasing function of u.

Substituting equation (3) into equation (2) yields the weak complementarity expenditure function:

$$E = \zeta\exp\left[\left(\frac{\gamma}{\beta}\right)(\delta q + \beta p)\right] - \frac{1}{\gamma}\left(\alpha + \beta p + \delta q + \frac{\beta}{\gamma}\right).$$

Applying duality, the money metric indirect utility function is specified as:

$$\Lambda(p, m, q) = \frac{1}{\gamma}\left[\exp\left(-\frac{\gamma}{\beta}\right)(\delta q + \beta p)\right] \times \left(\alpha + \beta p + \gamma m + \delta q + \frac{\beta}{\gamma}\right).$$

The utility difference of a program that changes the fishing quality from q^0 to q^1 is implicitly expressed as:

$$\Delta\upsilon = \upsilon_1\big(\Lambda(p, q^1, m - b), q^1\big) - \upsilon_0\big(\Lambda(p, q^0, m), q^0\big),$$

where b represents the compensated variation or the WTP for the program.

Following Hanemann (1984), the median compensated variation (b) can be obtained by setting the utility difference ($\Delta\upsilon$) equal to zero. Evaluating $\Delta\upsilon$, where $x(p, q^0, m) = 0$, assuming $\upsilon(\Lambda(p, q, m), q) = \Lambda(p, q, m) + \lambda q$, and noting from the recreation demand function that $q^1 - q^0 = x/\delta$ (to the extent quality affects demand for trips), we can explicitly solve for b:

$$\text{(4)} \qquad b = \left\{\frac{1}{\gamma}\left(x + \frac{\beta}{\gamma}\right) - \left(\frac{\beta}{\gamma^2}\right)\left(\exp\left(\frac{\gamma x}{\beta}\right)\right)\right\} + \left\{\lambda\Delta q\left[\exp\left(\left(\frac{\gamma}{\beta}\right)\left(\beta p + \delta q^1\right)\right)\right]\right\}.$$

Equation (4) provides a monetary measure of the change in welfare caused by the change in catch rate from q^0 to q^1. If the parameters of the equation can be estimated, then a monetary measure of the benefits of improving the catch rates q^0 to q^1 can be calculated. Recall the assumption on the utility function, $U\{f(x, z, q), q\}$, where q affects an angler's utility in two ways: (*a*) directly as an argument of $U(\cdot)$, and (*b*) indirectly through the number of recreational fishing trips. Therefore, the value of the improvement (*b*) can be decomposed into recreational indirect value (the first set of braces) and the direct value (the second set of braces).

The Econometric Specifications

This study combines the truncated travel cost data on the number of recreational fishing trips and the contingent valuation data on "yes"/"no" responses to a question about the respondent's WTP to maintain red snapper catch rates.

Truncated Travel Cost Model

When intercept data are used to estimate a TCM, each observation in the sample makes at least one trip to the recreational site. Thus the dependent variable, the number of recreational fishing trips, is truncated at one. Therefore, it is appropriate to specify the TCM as a truncated regression. The recreational fishing trip demand can be rewritten as: $x = \alpha + \beta p + \gamma m + \delta q + \omega e + \eta$, where α is the intercept term and β, γ, δ, and ω are estimated parameters for price (p), income (m), catch rate (q), and fishing experience in years (e), respectively, and η is a normally distributed error term with a mean of zero and variance σ_η^2. The density of a truncated random variable (the number of trips) is written as (Greene, 1993, pp. 684–685):

$$(5) \qquad f(x|x>0) = \frac{f(x)}{\text{Prob}(x>0)}.$$

The truncated normal density function in equation (5) can be expressed as:

$$f(x|x>0) = \frac{\dfrac{1}{\sqrt{\sigma_\eta^2 2\pi}} \exp\left[-\dfrac{1}{2}\left(\dfrac{x-\bar{x}}{\sigma_\eta}\right)^2\right]}{1 - \Phi\left(\dfrac{-\bar{x}}{\sigma_\eta}\right)},$$

where x is assumed normally distributed with mean $\bar{x} = \alpha + \beta p + \gamma m + \delta q + \omega e$, variance σ_η, and Φ is the standard normal cumulative distribution function (cdf).

The log-likelihood function associated with the truncated TCM is:

$$(6) \quad \ln L = \sum_i \left[-\frac{1}{2}\left(\ln(2\pi) + \ln(\sigma_\eta^2) + \left(\frac{x_i - \bar{x}_i}{\sigma_\eta}\right)^2\right)\right] - \sum_i \ln\left[\Phi\left(\frac{\bar{x}_i}{\sigma_\eta}\right)\right],$$

where i represents an individual respondent. This log-likelihood function is used to estimate a truncated TCM employing a maximum-likelihood procedure.[3]

Contingent Valuation Model

The CVM makes use of direct observation of answers to questions about WTP. In the survey questionnaire, respondents are first given a randomly suggested price to maintain the current red snapper catch rates, and then are asked if they are willing to pay that price. Respondents are assumed to know their preferences, but there are other components which are unobservable to researchers. Therefore, following Maddala (1983), assume the latent variable (y_i^*) is an underlying variable which is unobserved by researchers:

$$y_i^* = \boldsymbol{\beta}\mathbf{D} + \varepsilon_i,$$

where $\boldsymbol{\beta}$ is a vector of estimated parameters for a vector of explanatory variables ($\mathbf{D}$) which affect individual preference, and ε is the error term and assumed to be distributed normally with a mean of zero and variance σ_ε^2. What we then observe is a dummy variable (y_i), defined by:

$$y_i = \begin{cases} 1 & \text{if } y_i^* > 0, \\ 0 & \text{otherwise.} \end{cases}$$

The probability of $y_i = 1$ (i.e., the individual chooses to participate or, in a hypothetical contingent valuation survey, indicates he/she would be

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[3] One may argue that with the nature of recreation demand where the number of trips is a count integer, the count data distributions such as the Poisson or the negative binomial models are more appropriate than the continuous distribution. In this analysis, however, we prefer to use the continuous distribution as an approximation for the count distribution because of the complexity in the derivation of the bivariate density function (likelihood function) for the truncated Poisson or negative binomial TCM and CVM. Nevertheless, a general conceptual theory for the truncated Poisson and negative binomial models is provided by Gurmu and Trivedi (1992).

willing to pay the suggested price stated in the survey—in other words, a respondent answers "yes" to the suggested price) is calculated as follows:

$$\text{Prob}(y_i = 1) \equiv \text{Prob}(\text{“}yes\text{”}) = \text{Prob}(\varepsilon_i > -\boldsymbol{\beta}\mathbf{D}_i) = 1 - F(-\boldsymbol{\beta}\mathbf{D}_i),$$

where F is the cumulative distribution function of ε. For multiple observations of choice, the log-likelihood function can then be expressed as:

$$\text{(7)} \qquad \ln L = \sum_{i=1}^{n} \Big\{ y_i \ln\big[F(\boldsymbol{\beta}\mathbf{D}_i)\big] + (1 - y_i)\ln\big[1 - F(\boldsymbol{\beta}\mathbf{D}_i)\big]\Big\}.$$

This log-likelihood function is used to estimate the CVM employing a maximum-likelihood procedure.

Joint Contingent Valuation and Truncated Travel Cost Model

A joint CVM-TCM model was first estimated by Cameron (1992), and we build on her work and that of Niklitschek and Leon (1996). Even though the analytical model underlying our estimation procedure is based on these works, to our knowledge, this is the first study to combine the CVM with the truncated TCM.

Combining the stated preference (standard probit CVM model) and the revealed preference (truncated TCM) requires imposing restrictions on the parameters estimated and the relationship among the stochastic components associated with the number of trips (η) and with the discrete choice model (ε). The error structure associated with the number of trips and the discrete choice model, in general, is assumed to be correlated, ρ. By incorporating this feature into the joint model and assuming the errors have a bivariate normal distribution, $(\eta, \varepsilon) \sim BVN(0, 0, \sigma_\eta^2, \sigma_\varepsilon^2, \rho)$, the general probability density function of a bivariate normal distribution is given by (Cohen, 1955, pp. 884–889; Johnson and Kotz, 1972, p. 112):

$$f(\varepsilon, \eta) = \frac{\exp\left\{\dfrac{-1}{2(1-\rho^2)}\left[\left(\dfrac{\eta}{\sigma_\eta}\right)^2 - 2\rho\left(\dfrac{\eta}{\sigma_\eta}\right)\left(\dfrac{\varepsilon}{\sigma_\varepsilon}\right) + \left(\dfrac{\varepsilon}{\sigma_\varepsilon}\right)^2\right]\right\}}{2\pi\sigma_\eta\sigma_\varepsilon\sqrt{1-\rho^2}}$$

for $-\infty < \eta < \infty$, $-\infty < \varepsilon < \infty$, where $\sigma_\eta > 0$, $\sigma_\varepsilon > 0$, and $-1 < \rho < 1$. Then the *truncated* bivariate normal distribution, $f(\varepsilon, \eta \mid \eta > 0)$, can be expressed in terms of a bivariate normal distribution by adjusting for the truncation as follows:

$$f(\varepsilon, \eta \mid \eta > 0) = \frac{f(\varepsilon, \eta)}{\text{Prob}(\eta > 0)}.$$

Cohen (1955) has shown that the $f(\varepsilon, \eta)$ term can be expressed as the product of the marginal density function, $h(\eta)$, and the conditional density, $f'(\varepsilon \mid \eta)$:

$$f(\varepsilon, \eta) = h(\eta) f'(\varepsilon \mid \eta).$$

The marginal density function of η is normally distributed and is obtained from:

$$h(\eta) = \int_{-\infty}^{\infty} f(\varepsilon, \eta)\, d\varepsilon.$$

The conditional density function, $f'(\varepsilon \mid \eta) = f(\varepsilon, \eta)/h(\eta)$, is normally distributed with mean $\rho\eta(\sigma_\varepsilon/\sigma_\eta)$ and variance $\sigma_\varepsilon^2(1-\rho^2)$. With the knowledge of $h(\eta)$ and $f(\varepsilon \mid \eta)$, it can be shown that $f(\varepsilon, \eta) = \phi(\eta)\phi(\varepsilon \mid \eta)$. Therefore, the corresponding joint probability density function of the joint truncated TCM-CVM model is given by:

$$f(\varepsilon, \eta \mid \eta > 0) = \frac{\phi(\eta)\phi(\varepsilon \mid \eta)}{\text{Prob}(\eta > 0)}.$$

The likelihood function for the joint model is expressed as:

$$\text{(8)} \qquad L = \prod_{i \in (A)} \text{Prob}(\text{“}yes\text{,”}\ x \mid x > 0) \times \prod_{i \in (B)} \text{Prob}(\text{“}no\text{,”}\ x \mid x > 0),$$

where (A) represents the outcome of receiving a "yes" answer for the contingent valuation question, and (B) represents the outcome of a "no" response. The probability of taking recreational red snapper fishing trips and answering "yes" is defined as:

$$\text{Prob}(\text{“}yes\text{,”}\ x \mid x > 0) = \int_{-\Delta V}^{\infty} \frac{f(\varepsilon, \eta)}{\text{Prob}(x > 0)}\, d\varepsilon,$$

where $f(\varepsilon, \eta) = \phi(\eta) \times \phi(\varepsilon \mid \eta)$, and ΔV is the utility difference associated with the change in catch from q^0 to q^1 (Δq) and the simultaneous change in income by the bid amount (b).[4]

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[4] As shown in Hanemann (1984),

$$P_1 = \text{Prob}\{\text{a respondent answers “yes” to a suggested price}\} = \text{Prob}\{\upsilon(1, m-b, q^1; s) + \varepsilon_1 \geq \upsilon(0, m-b, q^0; s) + \varepsilon_0\}$$

and

$$P_0 = \text{Prob}\{\text{a respondent answers “no” to a suggested price}\} = 1 - P_1.$$

Letting $\varepsilon = \varepsilon_0 - \varepsilon_1$, the willingness-to-pay probability can be written as $P_1 = F(\Delta V)$, where

Similarly, the probability of taking recreational red snapper fishing trips and answering "no" is denoted by:

$$\text{Prob}(\text{``}no\text{,''}\ x|x > 0) = \int_{-\infty}^{-\Delta V} \frac{f(\varepsilon, \eta)}{\text{Prob}(x > 0)}\, d\varepsilon,$$

The log-likelihood function corresponding to equation (8) is:

$$(9)\quad \ln L = \sum_i \left[-\frac{1}{2}\left(\ln(2\pi) + \ln(\sigma_\eta^2) + \left(\frac{x_i - g x_i}{\sigma_\eta} \right)^2 \right) \right] - \sum_i \ln\left[\Phi_\eta\left(\frac{g x_i}{\sigma_\eta} \right) \right] + \sum_{i=1}^{n} \left\{ (\Delta\bar{\upsilon}) \ln[\Phi(\nu)] + (1 - \Delta\bar{\upsilon}) \ln[1 - \Phi(\nu)] \right\},$$

where

$$\nu = \frac{\left(\dfrac{\Delta V}{\sigma_\varepsilon} + \rho \dfrac{\eta}{\sigma_\eta} \right)}{\sqrt{1 - \rho^2}}.$$

This log-likelihood function [equation (9)] is used to estimate the joint CVM and truncated TCM using a maximum-likelihood procedure. The joint CVM and truncated TCM developed here is important and appropriate to the recreational fishing study since most of the typical recreational fishing survey data are obtained from intercept surveys or from anglers' log books where the number of fishing trips for each observation is likely to be nonzero. To demonstrate the usefulness of the joint model, we apply the CVM, truncated TCM, and the joint specifications to the case of the Gulf of Mexico recreational red snapper fishery.

Application to Recreational Fishery

Data

Most of the data for this application were obtained from a survey of Gulf of Mexico reef anglers, administered by KCA Research, Inc., for the National Marine Fisheries Service (NMFS) during 1991. In this survey, respondents were asked about their WTP for maintaining the red snapper population or maintaining the current red snapper catch rates:

> Would you be willing to pay $$$$ [randomly chosen dollar amount] on an annual basis for a management program designed to maintain exclusively red snapper catch rates and populations at their current levels assuming the alternative was the eventual elimination of the red snapper population?[5]

After screening for incomplete questionnaires (i.e., respondents answering "don't know" or "refused" were not included), 353 observations, or 41% of the total number of respondents, are usable. Because the survey focuses on the entire Gulf of Mexico reef fish recreational fishing trip, these 353 observations include both the red snapper recreational fishing trips and other non-red snapper fishing trips. Therefore, the reef fish identification question is used to screen for the red snapper recreational fishing trip. The recreational anglers were asked which reef fish species (up to three reef fish species) they targeted on their most recent fishing trip. If the red snapper species was one of these targeted species, then the fishing trip was defined as a recreational red snapper fishing trip. After this screening process, only 68 observations remained for the analysis.

This survey also provided individual information on price (travel expenditure), the number of recreational trips, household income, and the number of years of experience. The time cost has significant impact on estimating the recreation demand, and ignoring this cost would lead to an overestimate of the parameter related to price. In turn, this would lead to an underestimate of the consumer surplus (Bockstael, Strand, and Hanemann, 1987; Cesario and Knetsch, 1976; McConnell, 1975; McConnell and Strand, 1981). Consequently, the opportunity cost of time is included in the price variable consisting of transportation and other miscellaneous costs associated with the recreational trip. How the time cost is incorporated into the recreational demand function, however, depends on an assumption of work time. This study assumes some substitutability between work and recreational time for anglers.[6]

$$\Delta V = \left\{ b - \frac{x}{\gamma} - \left(\frac{\beta}{\gamma^2} \right)\left(1 - \exp\left(\frac{\gamma x}{\beta} \right) \right) \right\} \times \left[\exp\left(\left(\frac{\gamma}{\beta} \right)(\beta p + \delta q) \right) \right]^{-1} + \lambda \Delta q.$$

[5] This random dollar amount ranged from $10 to $500. Note the alternative scenario, where the red snapper population is terminated, seems unrealistic. This unrealistic question may also contribute to a higher bid, which in turn influences the willingness to pay for the CVM.

[6] This assumption is suggested by McConnell (1975), and McConnell and Strand (1981), and also is applied by Bockstael, Strand, and Hanemann (1987); Huang, Haab, and Whitehead (1998); and Parsons and Kealy (1992). This assumption seems realistic because anglers can use the red snapper recreational time for part-time jobs, other secondary jobs, or even other recreational activities. Therefore, by making red snapper recreational fishing trips, anglers forego some income to enjoy red snapper recreational fishing trips. With the inclusion of the time constraint, the recreational anglers maximize their utility function $U\{f(x, z, q), q\}$

Therefore, the recreational fishing trip demand can be rewritten as:

$$(10) \qquad x = \alpha + \beta(p + ktm(w)/w) + \gamma m + \delta q + \omega e + \eta,$$

where t represents a round-trip travel time and is calculated as distance from home to recreational sites (distance miles/45 miles per hour), m/w represents average hourly annual income and is calculated as household annual income divided by number of annual hours work, and k is an arbitrary number chosen to represent how anglers value time in comparison to their average income. Following McConnell and Strand (1981), this study chooses a value of 0.612 for k implying anglers value time at about 60% of their working hours.

The annual Marine Recreational Fisheries Statistics Survey conducted by the NMFS provided the data for the catch rate. The *Catch Rate* variable was constructed by first averaging the catch rates for the years 1989 and 1990 for different areas in the Gulf of Mexico, and then assigning each angler an average catch rate based on the area in which the angler fished. This average catch rate is used as a proxy for the expected fishing quality. Ideally, the catch rate should include fish that are kept and used for bait, filleted fish, and discards. However, due to the limited amount of information regarding catch rates, only the keep rate was used in this study; in other words, the catch rate is proxied by the keep rate.[7]

The mean value of each variable is as follows: *Trip* (22.1), *Travel Cost* ($95.7), *Income* in thousands of dollars ($48.9), *Catch Rate* (2.7), *Experience* (14.6), and *Bid* or WTP (162.3).

Huang, Haab, and Whitehead (1998), and Kling (1997) advise caution in pooling revealed and stated preference data. It is important that the revealed and stated preference data capture essentially the same preferences. In our analysis, the contingent valuation question asks about the individual's willingness to pay to maintain fishing quality. Similarly, the number of fishing trips taken is also positively affected by fishing quality. Thus, these data generally reflect the same underlying parameters and utility structure. There is, however, some reason for caution. The CVM question asks about a discrete change in the fish stock, while trip responses would be affected by marginal changes in the fishery. Hence, while we feel justified in pooling the data, some caveat should be acknowledged.

In addition, because the WTP under the CVM specification utilizes information on "yes"/"no" to the suggested price, this represents use and nonuse values for maintaining catch rates and preserving the red snapper population. Hence, the WTP under the CVM is viewed as the total value.

Empirical Results

The theoretical models described above are applied to obtain empirical estimates of the economic values of the Gulf of Mexico recreational red snapper fishery. The log-likelihood functions previously defined in equations (6), (7), and (9) are used to estimate the CVM, the truncated TCM, and the joint model, respectively. GAUSS's Maxlik library was used to maximize these log-likelihood functions.

Estimated Parameters

The estimated parameters for the CVM, the truncated TCM, and the joint model are presented in table 2. All signs of the estimated parameters are as expected, except for the *Income* parameter of the CVM and the *Experience* parameter of the joint model. However, these estimates are not significantly different from zero at the 10% critical level based on a one-tailed t-test. The significant inverse relationship between the *Travel Cost* parameter and the *Trip* variable of the truncated TCM and the joint model indicates that as price (travel cost) increases, fewer recreational red snapper trips are taken.

Likewise, the *Bid* parameter of the CVM shows a negative correlation with the probability of a "yes" response, as expected. The significant positive relationship between the *Catch Rate* parameter and the *Trip* variable of the truncated TCM and the joint

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subject to the budget and time constraints, respectively, $xp + z \le m(w)$ and $tx + w = T$, where p is travel expenditures (excluding opportunity cost of time), $m(w)$ is the annual income from working w hours, t is the number of hours required for the red snapper recreational trip, w is the amount of working hours, and T is the total hours available. If we solve for w and then substitute into the budget constraint, the Lagrangian for this problem is written as: $L = U\{f(x, z, q), q\} + \mu(xp + z - m(T - tx))$, and the first-order condition for this profit maximization using the Lagrangian becomes: $\partial U/\partial x = \mu(p + tm'(w))$, where $tm'(w)$ is opportunity cost of time or the income that recreationists forego to enjoy the recreational trip. By assuming the marginal earning of working $m'(w)$ is constant ($m'(w) = m(w)/w$), the recreational demand function can be expressed as: $x = \alpha + \beta(p + ktm(w)/w) + \gamma m + \delta q + \omega e + \eta$.

[7] The Marine Recreational Fisheries Statistics Survey (MRFSS) data set disaggregates catch into a variety of categories. Catch type A refers to kept fish, and catch type B1 denotes fish that are caught but were used for bait, discarded dead fish, and filleted fish. An accurate catch rate representing a bag limit should include type A and part of B1. However, only type A is used, because we could not appropriately distinguish the portion of catch type B1 which is subject to a bag limit. This may lead to a measurement error resulting in a downward bias in the catch estimate. However, we believe this problem is probably relatively minor since 72.06% of the sample is composed of private/rental boats, for which the relative proportion of filleted catch is much lower than for the other boats (e.g., party/charter boats).

Table 2. Econometric Results for the U.S. Gulf of Mexico Red Snapper Truncated Travel Cost, Contingent Valuation, and Joint Models

[1] Variable	[2] Parameter	[3] Truncated Travel Cost	[4] Joint TCM-CVM	[5] Contingent Valuation
Constant	$\hat{\alpha}$	−1.1329 (0.6621)	−0.9913 (0.8220)	−0.2013 (0.3251)
Travel Cost (price)	$\hat{\beta}$	−0.6268* (1.4815)	−0.3799* (1.6000)	
Income	$\hat{\gamma}$	0.6737 (0.9685)	0.0455 (0.2210)	−0.3075 (0.8141)
Catch Rate	$\hat{\delta}$	0.6850* (1.3509)	0.3898* (1.3960)	0.3108 (1.1191)
Experience	$\hat{\omega}$	−0.1511 (0.3624)	0.3636* (1.5510)	0.4442* (1.7774)
Change in Fishing Quality	$\hat{\lambda}$		4.9332 (0.8820)	
Bid (WTP)	$\hat{\beta}'$			−0.4661* (2.3824)
Std. Deviation for Travel Cost	$\hat{\sigma}_\eta$		1.4607* (3.7870)	
Std. Deviation for Contingent Valuation	$\hat{\sigma}_g$		7.8181* (1.6770)	
Correlation between errors	$\hat{\rho}$		−0.8445* (5.8650)	

Note: An asterisk (*) denotes statistical significance at the 0.10 level based on a one-tailed *t*-test. Numbers in parentheses are absolute *t*-ratio values.

model indicates that an increase in fishing quality (an increase in catch rate) shifts the recreational trip demand to the right. The *Change in Fishing Quality* parameter (i.e., the change in the fishing quality that directly affects the utility function), $\hat{\gamma}$, is positive but insignificant. This finding suggests the resource's direct value is relatively slight, i.e., respondents are not willing to pay much for a resource if they cannot exploit that resource for recreation. This result is not surprising since the population being surveyed was composed entirely of anglers who have demonstrated an interest in recreational red snapper fishing. The significance of the estimated correlation parameter between the CVM and truncated TCM errors, $\hat{\rho}$, indicates a high correlation between the CVM and the truncated TCM models. Therefore, it is appropriate to use the joint CVM and truncated TCM to estimate the WTP (Kling, 1997).

Willingness to Pay

Following Bockstael and Strand (1987), by using the anglers' utility specification in equation (1), there is an indirect assumption that the source of the error is due to the measurement error in the number of trips.[8] With this assumption, the predicted recreational fishing trips are used to estimate the value of changes in the recreational red snapper catch rate.

The benefit of keeping the red snapper catch rates from falling from the current rate to a rate of zero fish per angler is estimated from three different model specifications—CVM, truncated TCM, and the joint model. Caution should be taken in interpreting these welfare measures.

The CVM welfare estimate is calculated as the median WTP using the standard probit specification following Hanemann (1984); Cameron (1992); and Cameron and Quiggin (1994):

$$(11) \qquad WTP_i = -(\alpha + \gamma m_i + \delta q_i + \omega e_i)/\beta p_i .$$

[8] According to Bockstael and Strand (1987), the value of consumer surplus obtained will vary depending on the assumptions made about the error structure, i.e., depending on whether the error is assumed to arise from omitted variables, measurement, or preferences. Further, they show that consumer surplus derived under the omitted variable assumption tends to be larger in value than when estimated under the other assumptions.

The truncated TCM welfare estimate is represented by a compensating variation or WTP for a program to maintain fishing quality at q^0 (current catch rates) instead of falling to q^1 (zero catch rate per trip). This is calculated by substituting estimated parameters from equation (6), reported in table 2 (column 3), into the WTP equation:

$$(12)\quad WTP_i = \left\{\frac{1}{\gamma}\left(\hat{x}_i + \frac{\beta}{\gamma}\right) - \left(\frac{\beta}{\gamma^2}\right)\left(\exp\left(\frac{\gamma \hat{x}_i}{\beta}\right)\right)\right\}.$$

This WTP under the truncated TCM specification utilizes information on the demand for recreational red snapper fishing trips to impute the value of alternative catch rates. Hence, as captured in the truncated TCM, the benefit of maintaining the stock is its indirect effect on the angler's utility from recreational red snapper fishing trips. The WTP calculated here is the area between the recreational red snapper demand given the initial catch rate (at an average of 2.7 fish per trip) and the recreational red snapper demand given the subsequent catch rate at zero fish per trip.

In the third model, the joint welfare estimate is obtained by finding the dollar amount (b) which sets the utility difference (developed previously) equal to zero—i.e., the dollar amount which makes the individual indifferent between responding "yes" or "no." Specifically, using equation (4), we have:

$$(13)\quad \Delta V = \left\{b - \frac{x}{\gamma} - \left(\frac{\beta}{\gamma^2}\right)\left(1 - \exp\left(\frac{\gamma x}{\beta}\right)\right)\right\} \times \left[\exp\left(\left(\frac{\gamma}{\beta}\right)(\beta p + \delta q)\right)\right]^{-1} + \lambda \Delta q = 0.$$

The WTP under the joint model then can be explicitly solved:

$$(14)\quad b = \left\{\frac{1}{\gamma}\left(\hat{x} + \frac{\beta}{\gamma}\right) - \left(\frac{\beta}{\gamma^2}\right)\left(\exp\left(\frac{\gamma \hat{x}}{\beta}\right)\right)\right\} + \left\{\lambda \Delta q \left[\exp\left(\left(\frac{\gamma}{\beta}\right)(\beta p + \delta q)\right)\right]\right\}.$$

Based on the assumption that catch rates have effects on the utility function both indirectly and directly, $U\{f(x, z, q), q\}$, as discussed earlier, this WTP to maintain current catch rates (or maintaining the fishing quality at the current level) can be broken down into two values—indirect and direct. The indirect value [the first set of braces in (14)] is indirectly affected by catch rates through the number of recreational red snapper fishing trips. The indirect values are nonzero only if the number of recreational red snapper fishing trips is positive. The direct value (the second set of braces) is directly affected by catch rates and a change in catch rates (Δq) regardless of the number of recreational red snapper fishing trips.

Estimated welfare measures are presented in table 3. Although these WTP values are developed under different model specifications, they are derived from the same underlying utility functions. The CVM yields the highest WTP ($85.70 per angler), whereas the truncated TCM yields the lowest WTP ($9.85 per angler, or $0.45 per trip).[9] This result is not unexpected because the WTP under the CVM represents the total economic value, i.e., use plus nonuse values. Specifically, the WTP under the CVM specification utilizes information on "yes"/"no" to the suggested price which represents use and nonuse values for maintaining catch rates and preserving the red snapper population. This result also appears to be consistent with a pattern of "yea-saying" behavior (Hanley, Shogren, and White, 1997), where respondents tend to answer "yes" more frequently when the bid is not actually collected. The magnitude of the gap found here might be attributable to the unrealistic alternative scenario in the CVM question in which the catch rate drops to zero.

While a difference between the CVM and TCM values is not unexpected, the size of the difference is unexpectedly large, particularly when examined in light of Carson et al.'s (1996) findings that, on average, contingent valuation and revealed preference measures are quite close. An alternative explanation for the difference in the values might be that the TCM method is essentially valuing only one attribute of the resource. Under the truncated TCM, WTP is inferred from anglers' revealed behavior through the expenditures on the recreational red snapper fishing trip. When the CVM and the truncated TCM are jointly estimated, the WTP falls between the other two estimates. This result is expected because the joint model captures both direct and indirect effects of the catch rate on anglers' utility.

The estimated values in this study are most comparable to the Gillig, Ozuna, and Griffin (2000) and Haab, Whitehead, and McConnell (2000) studies identified in table 1. Gillig, Ozuna, and Griffin

[9] Alternatively, as noted by a reviewer, the total consumer surplus is the most direct welfare measure of the benefits of keeping the fishing quality from falling from q^0 (current catch rates) to zero. This is equal to the area under the recreational demand curve of the truncated TCM (which equals $10.40).

Table 3. Estimated Welfare Measures: Anglers' Willingness to Pay for Recreational Red Snapper Fishing (and coefficient of variation), $/Angler

Model	WTP to Maintain Current Catch Rates	WTP for an Additional One Fish
Truncated Travel Cost	9.85 (1.462)	3.65
Joint Truncated TCM-CVM	14.50 (0.855)	5.37
< Indirect Values	10.11	3.74
< Direct Values	4.39	1.63
Contingent Valuation	85.70 (1.640)	31.74

Note: Values in parentheses are coefficients of variation for mean WTP.

estimated consumer surplus per recreational red snapper angler ranging from $15 (using the negative binomial I model) to $47 (using the Poisson model). Haab, Whitehead, and McConnell reported a WTP of $3.04 per trip for one additional fish increase in historic catch or kept rate for bottom fish. The values estimated here are therefore consistent with other estimated values. However, our joint model uses only the 68 observations associated with trips targeted toward red snapper, while the approach used by Gillig, Ozuna, and Griffin required data from anglers who did not target red snapper. Hence, adoption of the joint model might often prove more attractive since it can be estimated using data which can be collected at substantially lower cost.

The coefficient of variation is applied to assess if the WTP from the joint model is more reliable or precise than the WTP from the individual CVM or truncated TCM (table 3). The coefficients of variation for the truncated TCM and the CVM are 1.462 and 1.640, respectively. In contrast, the coefficient of variation for the joint model is much smaller at 0.855. Clearly, by combining these individual models, as represented by our joint truncated TCM-CVM model, the precision of estimated willingness to pay can be improved.

Bag Limits Value

Without any doubt, tighter bag limits will harm the recreational red snapper fishery in the short run. But the question to be addressed here is: What will be the total cost to anglers of a one-fish reduction in the bag limits?[10] The total cost to anglers of a tightening of the bag limits can be calculated by multiplying the WTP for one additional fish per angler by the number of anglers. Holiman (1999) estimates the number of recreational red snapper anglers in the Gulf of Mexico during 1997–1998 at 2.1 million anglers. This suggests a total cost to anglers of a one-fish reduction in the bag limits at $7.60 million under the truncated TCM, $11.27 million under the joint model, and $66.65 million under the CVM. Given this total cost information, fishery decision makers can then evaluate whether the benefits of the policy outweigh the costs, and whether any compensation to the anglers is warranted.

Additionally, the costs of bag limits could be compared to the costs of achieving similar biological outcomes through other means. For example, would it be more cost-effective to impose tighter restrictions on the commercial fishery, or take more aggressive steps to reduce bycatch by the shrimp fleet? Since costs imposed on recreational fishermen are rarely reflected in market statistics, it is easy for these costs to be ignored.

It is important to note the results of this study are somewhat dated. The data are taken from the 1991 survey of Gulf of Mexico reef anglers, and only the type A catch rate is used, which may lead to a measurement error resulting in a downward bias in the catch estimate. Hence, these limitations should be taken into account, and when interpreted for their policy implications, our results should be used with caution.

Conclusion

Nonmarket valuation methods are applied to measure the value change in Gulf of Mexico recreational red snapper fishing quality. In addition to employing the contingent valuation method (CVM) and the truncated travel cost method (TCM) individually, the joint CVM and truncated TCM model is also adapted. As anticipated, the three different model specifications yield a wide range of welfare estimates. The CVM yields the highest WTP ($85.70), whereas the truncated TCM yields the lowest WTP ($9.85). The WTP of the joint model falls in between ($14.50).

[10] A change in the catch rate should also imply a change in the bag limit, or vice versa. This is because our study uses catch type A (kept catch) as a catch rate parameter, and imposing a bag limit will affect the number of fish kept.

Prior to this study, there have been no data available on the value of changes in the recreational red snapper fishing quality, making policies (regulations) on the shrimp, commercial, and recreational red snapper fisheries difficult to evaluate and implement. Additionally, the joint truncated TCM and CVM is a more common type of model conforming to most of the recreational data which are primarily collected through intercept or on-site survey methods.

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