Environmentally friendly agricultural practices: an application of the contingent valuation method

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Pour une agriculture respectueuse de l'environnement: application de la méthode d'évaluation contingente

Mots-clés:
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Résumé – Le rôle des polluants agricoles dans la dégradation de la qualité des eaux de surface et des eaux souterraines est progressivement devenu un vaste sujet d'inquiétude. Pour y répondre, le gouvernement propose des subventions destinées à encourager les agriculteurs favorables à l'utilisation de nouvelles pratiques plus respectueuses de l'environnement. Toutefois, comme ces subventions sont forfaitaires, il n'est pas possible de savoir ce que serait la réponse des agriculteurs si leur montant variait. Cet article présente un modèle permettant d'estimer la probabilité d'utilisation des pratiques en question, compte tenu des paiements incitatifs proposés. Pour analyser les résultats d'une enquête menée auprès d'agriculteurs de différentes régions des Etats-Unis, l'auteur utilise une nouvelle version du modèle d'utilité aléatoire.

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Key-words:
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***Summary** – Over time, public concern over the contribution of agricultural pollutants to the degradation of surface and ground water supplies has been increasing. To address this concern, one existing governement program provides incentive payments to farmers to encourage them to adopt more environmentally benign production practices than they currently use. However, current payment levels are fixed. Hence, farmer response to different incentive payment levels is not known. This paper presents a model for estimating the probability of farmer adoption of environmentally sound management practices as a function of offered incentive payments. A modification of the random utility model is used to analyze survey results for farmers in several regions of the USA.*

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IN response to increasing public concern over the contribution of agricultural pollutants to the degradation of surface and ground water supplies, the 1990 Food, Agriculture, Conservation and Trade Act (FACTA) authorized the USDA to initiate the Water Quality Incentive Program (WQIP). WQIP is administered by the Soil Conservation Service (SCS) through the Agricultural Conservation Program (ACP). Its goal is to mitigate the negative impacts of agricultural activities on ground and surface water supplies through the use of stewardship payments and technical assistance to operators who agree to implement approved practices. With these incentives, farmers are encouraged to experiment with more environmentally benign production practices than they otherwise would adopt. For most practices, the program offers a flat per-acre rate (usually around $ 10/acre) with a maximum of $ 3,500 per contract per year. In 1992 and 1993 the funding levels for WQIP were $ 6.75 million and $ 15 million respectively. Currently, farmers in only a small number of watersheds are eligible to enter the program. However, the issue has been raised (Sinner, 1990) of making this type of incentive payment program more widely available.

The WQIP incentive payments are not determined through market interaction. Since the current program offers only a flat rate per acre for each practice, a supply curve cannot be identified that measures the numbers of acres switched over to the preferred practice as a function of incentive payment level. Our goal is to model the probabilities of participation as a function of a range of incentive payment offers. This response function would be useful in studies comparing the benefits and costs of the various preferred management practices.

The USDA believes that the preferred practices examined in this paper are profitable for the farmer. Yet, even though their implementation should theoretically boost profitability, not all farmers who could adopt these practices have done so. For farmers in the data set used here, current adoption of the discussed practices ranges from 7 percent to 73 percent. Some of the nonadoptors may not be able to adopt the practice for some physical reason[1]. However, most of the nonadoptors can use the practices but have not done so for reasons not directly pertaining to profitability. One reason may be that the farmer is risk averse: even if the alternative practice might appear profitable on paper, the farmer may be unwilling to adopt the practice unless the farmer sees neighboring farmers adopting it. Another reason for not adopting the practice might be that the farmer either has no, or insufficient, information about the alternative practice. Hence, an empirical comparison of profits or costs under the old and the new practices will not provide enough in-

[1] For instance, a farmer who does not have any livestock or poultry may not be interested in performing manure testing.

formation to determine the necessary incentive payment to encourage adoption. To avoid these problems associated with estimating minimum willingness to accept (WTA) to change practices as the difference in cost or profit between the two states. I will use a direct revelation technique based on a random utility model for assessing WTA. This model is based on the dichotomous choice contingent valuation method (CVM) method used in the nonmarket valuation literature*.

DERIVATION OF THE RANDOM UTILITY MODEL USED TO ASSESS THE FARMERS' WILLINGNESS-TO-ADOPT FUNCTION

Hanemann's (1984) Random Utility Model (RUM) provides a theoretical foundation for deriving the parameters necessary for estimating the farmers' response function to the incentive payments. From the utility theoretic standpoint, an individual is willing to accept $\$C$ to change his activities or accept a decrease in the provision of a good if the individual's utility after the change is at least as great in the initial state, *i.e.*, if $U(0,y;x) \leq U(1,y + C;x)$, where 0 is the base state; 1 is the state with the increase in the environmental amenity; y is individual i's income; and x is a vector of other attributes of the individual that may affect the WTA decision. An individual's utility function $U(i,y;s)$ is unknown due to components of it that are unobservable to the researcher, and thus, can be considered a random variable from the researcher's standpoint. The observable portion is $V(i,y;x)$, the mean of the random variable U. Because farmer income may fall, or possibly even rise, with participation in the program, the value C in the condition $U(0,y;x) \leq U(1,y + C;x)$ should be rewritten as $C* + \delta$, where δ is state 0 pecuniary costs less state 1 pecuniary costs. Hence, C can be considered a "net" incentive payment. Note that δ can be positive; due to some nonpecuniary costs, a farmer may not have switched to the preferred practice even if δ is positive. With the addition of an error ε_i where ε_i is an *i.i.d.* randome variable with zero mean, the farmer's decision to acccept $\$C$ can be re-expressed as:

$$V_0(y;x) + \varepsilon_0 \leq V_1(y + C;\, x) + \varepsilon_1 \qquad (1)$$

If $V_i(y;x) = \gamma_i + \alpha y$, where $\alpha > 0$, for $i = 0,1$, then the farmer is willing to accept $\$C$ for the change if $\gamma_0 + \alpha y + \varepsilon_0 \leq \gamma_i + \alpha(y + C) + \varepsilon_1$.[2]

* The views expressed in this paper are solely those of the author and do not necessary reflect the views of the US Department of Agriculture.

[2] In practice, the parameter γ can be considered to be a grand constant, which is a sum of any number of explanatory variables (except the price variable) times their means.

The decision to not accept $\$C$ can be expressed in a probability framework as $Pr\{WTA \leq \$C\} = 1 - Pr\{WTA \leq \$C\} = 1 - Pr\{V_0 + \varepsilon_0 \leq V_1 + \varepsilon_1\} = 1 - Pr\{\varepsilon_0 - \varepsilon_1 \leq V_1 - V_0\}$, where $V_1 - V_0 = \gamma + \alpha C$, and where $\gamma = \gamma_1 - \gamma_0$. Since $V_1 - V_2 = \gamma + \alpha C$ is generated directly from the utility model given above, it is compatible with the theory of utility maximization. If the normal cumulative probability density function is applied to this stochastic framework for the utility difference model,

$$Pr(WTA \leq C) = 1 - F_\varepsilon(-(V_1 - V_0)) = 1 - F_\varepsilon(-(\gamma + \alpha C)) \qquad (2)$$

Because the utility difference function can be expressed in this probability framework, the logit or probit regression models (to name the readily available qualitative dependent variable programs) can be used to obtain the coefficients estimates.

For an assessment of the incentive program, the mean, or median value is of secondary importance to estimating the probabilities of participation in the program for a schedule of incentive payments. These can simply be obtained through $P_i = F_\varepsilon(\Delta_i)$[(3)]. From a cost-effectiveness standpoint, the optimal rates of acceptance may not be the same for each practice[(4)].

The dichotomous aspect is that the respondent is prompted to provide a yes or no response to a dollar bid amount contained in the valuation question. The bid amount is varied across the respondents[(5)]. While this is the basic and most common referendum approach, variations on this approch do exist[(6)]. This method, in particular, is asserted to reveal accurate statements of value since the format provides reasonable incentives for value formulation and reliable value statement (Hoehn and Randall, 1987; US Department of Commerce, 1993). In fact, in the proposed NOAA guidelines for conducting natural resource damage assessment using CVM, the panel suggested that all CV studies should use the referendum (or more generally, the dichotomous choice) format.

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(3) Hanemann (1989; 1984) and Cameron (1988) discuss other functional forms for estimating the mean value.

(4) In addition to developing the farmer participation equation as a function of the offer amount, we may also like to know the amount of acres the farmer will enroll given the decision to participate. To do this, we could use a model that estimates acreage to be enrolled conditional on a "yes" response to the adoption question. This procedure is beyond the scope of this paper.

(5) Cooper (1993) presents a method for determining the appropriate range of bids to include in the surveys.

(6) One modification is to ask a second referendum question: if the respondent answered "yes" ("no") to the bid value in the first question, the respondent is prompted to answer a follow up question in which the offered bid value is higher (lower) than the bid amount in the first question (Hanemann, Loomis, and Kanninen, 1991). This double-bounded version, which should give a more precise estimate of the welfare benefit, has the same utility theoretic properties as the single bounded approach. It is most useful in personal interview instruments, and is not practical for mail surveys.

DATA DESCRIPTION

The 1992 Area Studies project is a data collection and modelling effort undertaken jointly by the Economic Research Service (ERS), the US Geological Survey (USGS), and the National Agricultural Statistical Service (NASS). For 1992, data on cropping and tillage practices and input management were obtained from comprehensive field and farm level surveys of about 1,000 farmers apiece for 1992 cropping practices in each of four critical watershed regions: the Eastern Iowa and Illinois Basin areas, the Albermarle-Pamlico Drainage Area covering Virginia and North Carolina, the Georgia-Florida Coastal Plain and the Upper Snake River Basin Area. These study areas were selected from within the set of US Geological Surveys's National Water Quality Assessment (NWQA) sites and sample sites were chosen to correspond to SCS's National Resource Inventory (NRI) so that information on the physical characteristics corresponding to farming activities would be available. For example, slope and erosion potential of the soil are likely factors influencing the decision to adopt conservation tillage.

Information about the extent of the farmers' current use of the preferred practices as well as their willingness to adopt these practices if they do not currently use the practice were provided by a supplemental questionnaire. Respondents to the comprehensive questionnaire were asked to complete and mail in this additional section. For the final analysis, 1,261 observations were available. No participants in existing WQIP programs were found among the survey respondents. Several other practices where included in the survey but the data on them were not analyzed.

The practices analyzed here, a short description of each, and the current incentive payment levels are:

Conservation Tillage (CONTILL) – Tillage system in which at least 30% of the soil surface is covered by plant residue after planting to reduce soil erosion by water; or where soil erosion by wind is the primary concern, at least 1,000 pounds per acre of flat small grain residue-equivalent are on the surface during the critical erosion period. Current WQIP incentive payment does not exceed $12 per acre for this practice.

Legume Crediting (LEGCR) – Nutrient management practice involving the estimation of the amount of nitrogen available for crops from previous legumes (*e.g.* alfalfa, clover, cover crops, etc.) and reducing the application rate of commercial fertilizers accordingly. Current WQIP incentive payment does not exceed $10 per acre for this practice.

Manure Testing (MANTST) – Nutrient management practice which accounts for the amount of nutrients available for crops from applying livestock or poultry manure and reducing the application rate of commercial fertilizer accordingly. Current WQIP incentive payment does not exceed $10 per acre for this practice.

Split Application of Nitrogen (SPLTN) – Nutrient management practice whereby one-half or less of the required amount of nitrogen for crop production is applied at or before planting, with the remainder applied after emergence, in order to supply nutrients more evenly and at times when the crop can most efficiently use them. Current WQIP incentive payment does not exceed $10 per acre for this practice.

Soil Moisture Testing (SMTST) – Irrigation water management practice in which tensionmeters or water table monitoringwells are used to estimate the amount of water available from subsurface sources. Current WQIP incentive payment does not exceed $10 per acre for this practice.

All of these practices are currently being supported by WQIP. For the willingness to adopt question for all of the practices except conservation tillage the bids offered are $2, $4, $7, $10, $15 and $20. For conservation tillage the bids are $4, $6, $9, $12, $18 and $24. The bid ranges were chosen to cover what we perceived to be the likely range of WTA. The bids were randomly assigned with equal probability to the surveys(7). The specific referendum CVM question asked to the farmer is *"If you don't use this practice* (listed in the question) *currently, would you adopt the practice if you were given a $X payment per acre?"* (answer "yes" or "no").

The pool of variables from which the explanatory variables were drawn is:

EDUC - Formal education of operator
EINDEX - Sheet and rill erosion index
EXPER - Farm operator's years of experience
SNT - Soil nitrogen test performed in 1992 (dummy)
TISTST - Tissue test performed in 1992 (dummy)
CTILL - Conservation tillage used in 1992 (dummy)
PESTM - Destroy crop residues for host-free zones (dummy)
ANIMAL - Farm type-beef, hogs, sheep (dummy)
GRAINS - Farm type-cash grains (dummy)
ROTATE - Grasses and legumes in rotation (dummy)
MANURE - Manure applied to field (dummy)
HEL - Highly erodible land (dummy).

Even though the above questions are framed in the WTA format, and hence, are not income constrained, we believe that they may be more incentive compatible than many WTP survey questions. Some level of in-

(7) The survey procedures in place did not allow a more complex allocation of bids. See Cooper (1993) for other possible surveys designs.

centive compatibility is likely as many of the respondents may quite rationally believe that their responses may influence the setting of incentive payments-related policies. If contract-holders do believe that the results may influence policy, then exaggerating their WTA may suggest to Congress that the program is too expensive and increase the probability that the program will be dropped or reduced in magnitude. Under-reporting WTA may lead to a re-evaluation of current payments with the result that the farmer may be offered payments lower than his reservation price.

Table 1. **Probit results for model for the decision to adopt the alternative management practices** [(a)]

	CONTILL	SPLTN	LEGCR	MANTST	SMTST
Variable			Coefficient Estimates		
CONST	-0.2863 (-0.9420)	-0.6686** (-3.0670)	-1.8774** (-7.8970)	-1.5751** (-7.4760)	-1.5574** (-7.6660)
BIDVAL	0.0198* (1.9400)	0.0433** (5.1090)	0.0303** (3.3270)	0.0269** (3.3620)	0.0324** (4.1570)
EDUC	-0.0666 (-1.2250)	-0.0308 (-0.7420)	0.1002* (2.2940)	0.0630 (1.6290)	0.0959** (2.5420)
CTILL	0.0906 (0.5060)	— —	— —	— —	— —
HEL	-0.1139 (-0.5750)	—	—	—	—
TISTST	—	0.8757* (2.0950)	0.2365 (0.7650)	-0.2708 (-0.7980)	—
EXPER	-0.0079 (-1.3850)	-0.0133** (-2.9680)	-0.0004 (-0.0910)	-0.0105** (-2.4010)	-0.0096* (-2.2130)
PESTM	0.1869 (1.1270)	—	—	—	—
ROTATE	0.0306 (0.0980)	0.0356 (0.1550)	0.4422* (1.6920)	0.3230 (1.5450)	0.2034 (0.9720)
MANURE	-0.0202 (-0.0900)	-0.2206 (-1.4320)	-0.3039 (-1.5650)	0.3161** (2.3540)	—
ANIMAL	—	0.0742 (0.5740)	0.2942* (2.1290)	0.4385** (3.7760)	—
obs.	331	683	860	1101	1070

[(a)] asked to farmers who do not currently use the practice
Coefficient divided by standard error in parentheses
* = significance of 5 % ; ** = significance of 1 %.

ESTIMATION RESULTS

Table 1 presents the weighted probit results for the WTA for adoption questions[(8)]. The key variable, BID, is of the correct sign and is significant to at least the 1 percent level for all practices except CONTILL, where it is significant at the 5 percent level. However, it was difficult to find significant explanatory power among the explanatory variables. Of the other variables common to all five practices, the coefficient on years of education was significant and positive for two of the five variables. To test for regional differences in the responses, regressions were tried with dummies for the regions but none of the associated coefficients were significant. The difficulty in observing variables that actually factor into the farmer's decision on whether or not to adopt the practice demonstrates the benefits of the stated preferences approach used here over an indirect approach, such as one that relies on estimating a profit function. At any rate, as the note at the bottom of table 2 demonstrates, the inclusion of explanatory variables in dichotomous choice CVM regresssions generally have relatively small effects on the mean and median WTA or WTP measures.

Table 2. Median minimum expected willingness to accept (per acre) to encourage use of the practices

Practice	Median	Standard error[(a)]	γ[(b)]	α[(c)]
	Dollars	*Dollars*	*Coefficient*	*Coefficient*
CONTILL	31.67	10.38	-0.6275	0.019814
SPLTN	25.35	3.14	-1.09664	0.043256
LEGCR	50.96	12.18	-1.54205	0.030255
MANTST	56.59	13.76	-1.52341	0.026919
SMTST	45.76	8.51	-1.48393	0.032432

[(a)] Standard Error of the median value calculated using an analytic approach (Cooper, 1994)

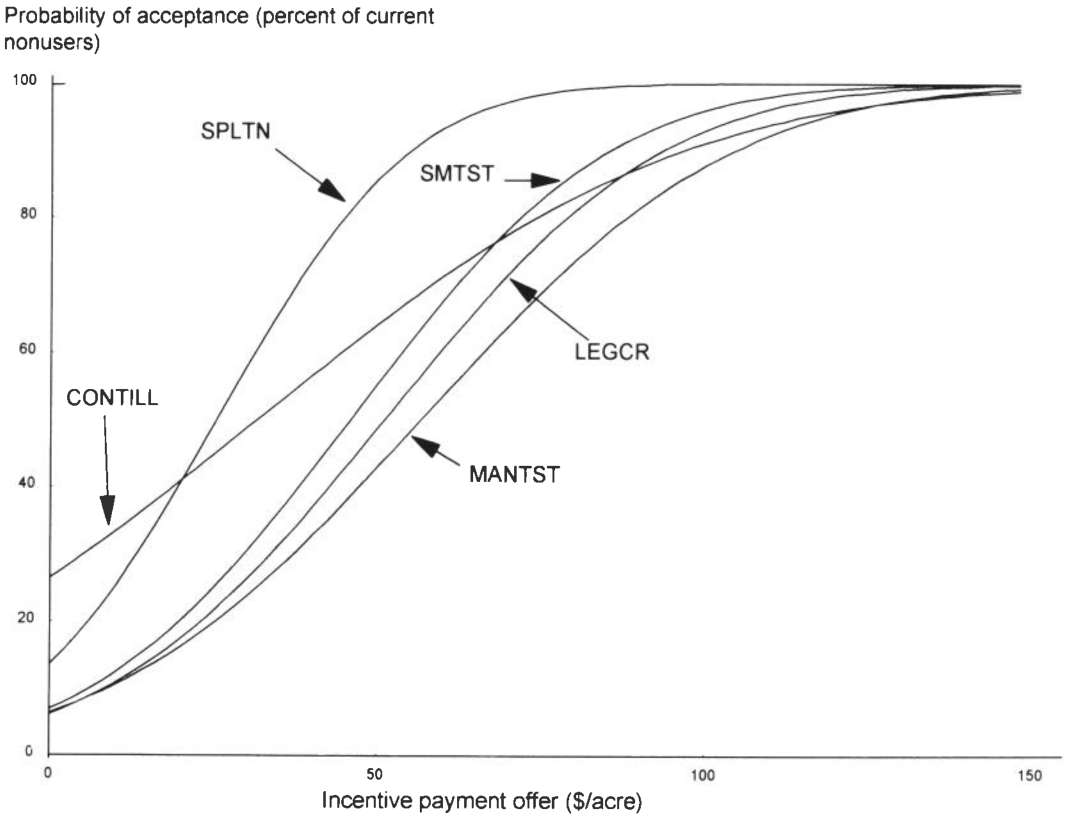
[(b)] & [(c)] Probit estimates of coefficients in equation 2. (α is the sum of all explanatory coefficients (except BID from table 1) times their respective variable means. Using the constant and the bid value as the only regressors produces median values of $33.84; 25.91; 47.40; 54.80; 45.23 and 33.84, respectively, for the practices listed above.

[(8)] Because the survey sampled some regions at higher rates than others (e.g. noncropland areas were sampled at lower rates than cropland areas), the data were scaled by sampling weights. Multiplying the data by the weights gives greater weight to the observations from the regions with the lower probability of being selected and decreases the weight to the observations from the regions with higher probability of being selected. For estimation, the weights are multiplied by the sample size divided by the sum of the weights so that the sum of the weights across the observations is the sample size (Greene, 1992).

Model Applications

Given that the WTA estimates necessary to achieve 50 percent adoption are much higher than the current payments levels, it is not surprising that participation in the program by eligible farmers is quite low for many of the practices (table 2). However, given that encouraging participation is not costless, a cost-efficiency or cost-benefit analysis could be used to determine what participation rates, and hence, what offer amounts would be desirable for each practice. To do this, a farmer response function is necessary. As discussed earlier, probit coefficient results can be plugged into the normal cumulative density function to predict probability of adoption of the practices for different incentive payment levels. In conjunction, for those farmers who are predicted to adopt the practice at a given payment level, the continuous equation can be used to predict the number of acres enrolled.

Figure 1. **Response curves for the subsidized practices**



Using the univariate probit coefficients for the WTA equation for each of the practices, figure 1 graphs the relationship between the offer amount and the probability of acceptance for those farmers who do not currently use the practices.

These response functions could be used in a mathematical programming model to determine the incentive payments that maximize the net benefits of the incentive payment program, where net benefits are defined as the change in environmental benefits (in dollars) due to the switch to the preferred practices minus the total incentive payment outlays. Further research is needed to put a monetary value on the environmental benefits of the changes in farm management practices.

CONCLUSION

Farmers can be encouraged to voluntarily adopt environmentally sound management practices through the use of incentive payments. Current USDA practice is to offer a fixed "take it or leave it" payment per acre to those not currently using the desired practices. Hence, there is insufficient observed data to model the probability of farmer adoption of the environmentally sound management practices as a function of the payment offer. Without this function, one does not know at what level to set incentive payments to achieve desired levels of participation. This case study uses a direct revelation technique based on a random utility model to develop and estimate models predicting farmer adoption of the practices as a function of the payment offer. These results can be used in a cost-benefit analysis to best decide how to allocate the program budget among the preferred production practices.

In a nontraditional use of nonmarket valuation techniques, this report has presented a case study of an application of dichotomous choice CVM to the farm producer side to predict the costs to the governement of proposed agricultural policies. Examples of other possible applications of dichotomous choice CVM techniques include estimation of the farmer's minimum willingness to accept to encourage the farmer to install filter strips on the farmer's property and the farmer 's minimum willingness to accept to encourage participation in the Conservation Reserve Program.

REFERENCES

CAMERON (T.A.), 1988 — A new paradigm for valuing non-market goods using referendum data: maximum likelihood estimation by censored logistic regression, *Journal of Environmental Economics and Management*, 15, pp. 355-379.

COOPER (J.), 1994 — A comparison of approaches to calculating confidence intervals for benefit measures from dichotomous choice contingent valuation surveys, *Land Economics*, 70(1), pp. 111-122.

COOPER (J.), 1993 — Optimal bid selection for dichotomous choice contingent valuation surveys, *Journal of Environmental Economics and Management*, Vol. 24, pp. 25-40.

GREENE (W.), 1992 — *Limdep: User's Manual and Reference Guide, Version 6.0*, Econometric Software Inc., Bellport, New York.

HANEMANN (M.), 1989 — Welfare evaluations in contigent valuation experiments with discrete response data: Reply, *American Journal of Agricultural Economics*, 71(4), pp. 1057-1061.

HANEMANN (M.), 1984 — Welfare evaluations in contigent valuation experiments with discrete response data, *American Journal of Agricultural Economics*, 66(4), pp. 332-341.

HANEMANN (M.), LOOMIS (J.) and KANNINEN (B.), 1991 — Statistical efficiency of double-bound dichotomous choice contingent valuation, *American Journal of Agricultural Economics*, 73(4), pp. 1255-1263.

HOEHN (J.) and RANDALL (A.), 1987 — A satisfactory benefit cost estimator from contingent valuation, *Journal of Environmental Economics and Management*, 12, pp. 226-247.

MITCHELL (R.) and CARSON (R.), 1989 — *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Washington, DC, Resources for the Future.

SINNER (J.), 1990 — We can get more for our tax dollars, *Choices*, 5(2), pp. 10-13.

US DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERE ADMINISTRATION, 1993 — Proposed rules: natural resource damage assessment, *Federal Register*, 58(10), pp. 4601-4614, 15 CFR, Chapter IX.