Uncertain Recreation Quality and Wildlife Valuation: Are Conventional Benefit Measures Adequate?

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Theoretical issues and empirical approaches are discussed for benefit estimation when wildife resource users face uncertain recreation quality. It is argued that selection of an appropriate benefit measure is predicated upon differing attitudes toward quality uncertainty, expected utility maximization, and risk. In particular, it is shown that for specific groups in the user population, conventional benefit measures do not apply, and alternative welfare measures are developed. Implications for restructuring contingent valuation procedures are discussed.

Key words: amenity benefits, option value, uncertainty, wildlife valuation.

In estimating benefits attributable to wildlife resources, it is important to distinguish individuals based on their probability of site use. For individuals with no chance of actually using a wildlife recreation area but who are still willing to pay to insure the continued availability of the site, existence values need to be included in any benefit estimation procedure. Existence benefits for nonusers were originally discussed by Krutilla and have been attributed to a variety of motivations including vicarious consumption (Daly and Giertz), bequest values (Krutilla and Fisher), altruism (Randall and Stoll), and stewardship (Fisher and Raucher).[1] In contrast to nonuser benefits, the vast majority of the valuation literature has addressed theoretical and empirical issues involved with user benefits, benefits attributable to individuals who are certain of participating or who have some positive probability of active demand. For certain demanders of wildlife resources, conventional Hicksian surplus measures of benefits are appropriate. For uncertain demanders, conventional benefit measures do not apply directly and require additional refinement (Krutilla and Fisher).

Issues involved in benefit estimation under conditions of participation uncertainty have been discussed by a variety of authors including Bishop, Smith (1982), and Freeman (1979, 1984), and more recently by Plummer and Hartman. This study departs from the demand uncertainty literature by considering wildlife valuation issues which arise when certain demanders face uncertain recreation quality. The objective of the paper is to elucidate the benefit measures applicable under alternative scenarios involving uncertain recreation quality. Neither existence values for nonusers nor option values attributable to demand uncertainty apply to situations involving quality uncertainty. Literature focusing on user benefits attributable to wildlife resources given quality certainty is substantial. Representative studies for consumptive uses of wildlife, such as recreational fishing and hunting, include Brown, Singh, and Castle; McConnell; Wilson; Anderson; and Sandrey, Buccola, and Brown. While these investigations were couched in the framework of certain recreation quality under a single-use management policy, a recent study by Cory and Martin extended empirical work

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[1] For a discussion of nonuser benefits, see Brookshire, Eubanks, and Sorg.

in this area to the multiple-use setting. Similarly, previous work has addressed nonconsumptive uses of wildlife under conditions of certain recreation quality with representative studies including Hay and McConnell, Stoll and Johnson, and Cicchetti and Smith. However, once recreation quality is viewed as uncertain, previous research is much more limited. Welfare-theoretic issues have been addressed in a multiple-site context by both Maler and Freeman for the case of changing recreation quality from one certain level to an improved certain level. Gallagher and Smith extended previous theoretical work by examining benefit measures appropriate for improving the probability of enjoying a high-quality recreation experience. Plummer and Hartman discuss the bias introduced by reliance on consumer surplus as a benefit measure when the quality of an environmental amenity is uncertain. Empirical work on measuring benefits under conditions of uncertainty has not addressed recreation quality but has been limited to demand uncertainty (Desvousges, Smith, and McGivney; Greenley, Walsh, and Young).

In the following sections, theoretical and empirical issues are discussed for benefit estimation involving certain demanders facing uncertain recreation quality. In the next section alternative theoretical measures of wildlife benefits are presented, followed by a discussion of the conditions under which a particular benefit measure applies. Finally, in the last section specific estimation procedures are proposed and the implications for contingent valuation instruments outlined.

Alternative Benefit Measures: Theoretical Considerations

Consider an individual who is uncertain about the recreation quality associated with the use of wildlife resources (e.g., uncertainty about having a successful hunt, sighting a particular rare bird, or the size of a fish catch). How should the benefits generated by policies which insure continued availability of the resources be measured? The measurement problem is one of determining the maximum expected value of contingency payments for which the uncertain user would voluntarily contract. Payments are contingent in the sense that an individual may be willing to pay different amounts depending on the quality of the recreation experience. For simplicity, assume that there are only two states of the world for the user within a given period: a state in which the quality of the recreation experience can be characterized as either high or low.[2] In this framework, benefit estimation would require identification of contingent-payment pairs for which the user facing quality uncertainty would contract to guarantee continued availability of a wildlife recreation area: a payment of C_H if the high-quality state should occur or a payment of C_L if the low-quality state materializes. Having identified these contingent-payment possibilities, the pair yielding the largest expected value is the appropriate measure of maximum willingness to pay.

Expected Consumer Surplus as a Benefit Measure

Agreeing to a contingent-payment scheme is assumed to guarantee supply of wildlife resource services. If no such payment plan is contracted, the uncertain user foregoes these services and utility in the absence of the wildlife resources becomes $\bar{U}$, where

$$\bar{U} = U(Y, P, X, O), \tag{1}$$

and U is indirect utility function without access to the wildlife resources, Y is income, P is vector of relative prices, X is vector of additional factors affecting utility, and O is unavailability of wildlife resources.

This utility outcome is illustrated in figure 1a by point g, where utility is portrayed as state dependent in such a way that the same income level provides a higher level of utility in the high-quality state than in the low-quality state.[3]

A rational individual would be unwilling to agree to any contingent-payment plan which would make him worse off (i.e., results in an expected utility level less than $\bar{U}$). One possible payment scheme that would not violate this condition involves Marshallian expected surplus ($E[S]$). Letting S_H and S_L represent con-

[2] The theoretical results presented here could readily be generalized to a range of recreation quality states.

[3] Smith (1982), Freeman (1984), and Plummer all discuss the implications of state-dependent utility functions for valuing natural amenities when demand is uncertain.

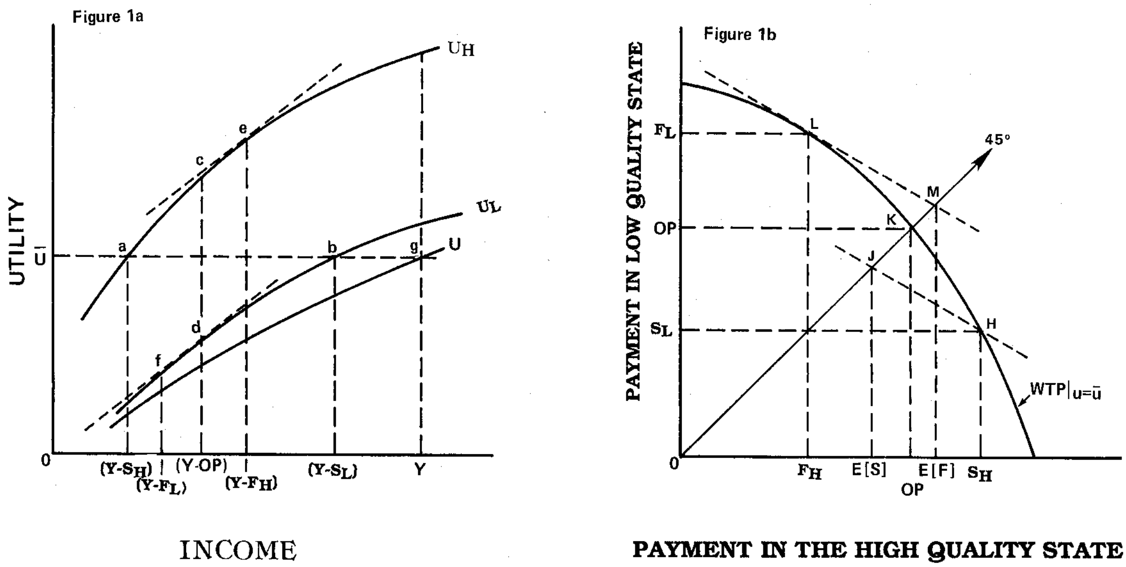

Figure 1. Uncertain recreation quality and wildlife resources: alternative benefit measures

sumer surplus in the high- and low-quality states, respectively,

(2) $$E[S] = \eta_H \cdot S_H + \eta_L \cdot S_L,$$

where S_H is defined by $U_H(Y - S_H, P, X, l) = U(Y, P, X, O)$; S_L is defined by $U_L(Y - S_L, P, X, l) = U(Y, P, X, O)$; U_H and U_L are the utility functions in the high- and low-quality states, respectively; η_H and η_L are the probabilities of being in the high- and low-quality states, respectively; and l indicates that the wildlife resources are available.[4]

As illustrated in figure 1a by points *a* and *b*, agreeing to a contingent-payment contract of (S_H, S_L) will not make the uncertain user worse off in terms of expected utility, while insuring supply. Thus, this contingent contract is one measure of the individual's willingness to pay and is illustrated in figure 1b by point *H*, where S_H is paid in the high-quality state, S_L is paid in the low-quality state, and expected utility is $\bar{U}$.[5]

[4] In this analytic framework, uncertainty is generated only by recreation quality since income is known and participation is certain.

[5] It is worth noting that an $E[S]$ contract not only results in an expected utility level of $\bar{U}$ but also eliminates variability in utility outcomes. That is, regardless of which quality state materializes, utility will be $\bar{U}$. Throughout the discussion of benefit measures, it is assumed that the individual is a strict expected utility maximizer and is indifferent between contingent contracts of differing variability but identical levels of expected utility.

Option Price as a Benefit Measure

A second possible benefit measure involves option price (*OP*). Option price is the maximum state-independent payment the individual would be willing to make to insure supply; that is, *OP* is defined by the following condition:

(3) $$\bar{U} = \eta_H \cdot U_H(Y - OP, P, X, l) + \eta_L \cdot U_L(Y - OP, P, X, l).$$

As with $E[S]$, a contingent-payment contract of (*OP*, *OP*) will again insure supply without making the uncertain user worse off. This benefit measure is illustrated in figure 1a by points *c* and *d*, where, for graphical purposes, it is assumed that $\eta_H = \eta_L = .5$. Thus, *OP* is a second measure of an individual's *WTP*, where *OP* is paid regardless of which quality state is realized and expected utility is again $\bar{U}$ (point *K* in figure 1b).

The difference between *OP* and $E[S]$ is called option value (*OV*). Freeman, Bishop, Graham, Smith (1982, 1984), and others have examined conditions under which the size and sign of *OV* is determinate. This literature can be useful in adjusting consumer surplus benefit estimates under specific circumstances outlined in Graham and in Cory and Saliba.

The Expected Value of Fair-Bet Contingent Payments as a Benefit Measure

The third benefit measure discussed involves payments that are, like the expected surplus payments (but unlike option price), state dependent. As demonstrated by Cory and Saliba, the process of collecting state-dependent payments is connected with no significant obstacles not inherently involved with collecting state-independent payments. To collect either option price or state-dependent payments, the following would be necessary: (*a*) uncertain users would have to be notified that a contract must be signed to guarantee the availability of wildlife resources, (*b*) exclusion would have to be possible, and (*c*) contracts would have to be enforceable. An option price contract could be implemented by collecting this amount and informing the user that there will be no refund at the end of the period regardless of which quality state is realized. A contingent contract could be implemented by collecting the payment in the high-quality state or the payment in the low-quality state, whichever is larger, and refunding the difference if required. The additional requirements, then, for using state-dependent payments include monitoring high or low quality for users and mailing refunds when necessary. Compared to the total cost of going through a hypothetical compensation exercise, the costs of monitoring and mailing refunds is likely to be small and may not constitute a compelling defense of option price.[6]

Once state-dependent payment schemes are recognized, contingent-payment combinations that result in an expected utility level of $\bar{U}$ are given by the willingness-to-pay locus developed by Graham. This locus consists of all contingent-payment pairs (C_H, C_L) that satisfy the following:

$$\bar{U} = \eta_H \cdot U_H(Y - C_H, P, X, I) + \eta_L \cdot U_L(Y - C_L, P, X, I). \tag{4}$$

The definition of this locus insures that expected utility when payments are made and the good is available is equal to expected utility when no payments are made and the good is unavailable, $\bar{U}$. That is, an individual is indifferent between making any of the pairs of contingent payments on the locus and being guaranteed access to the resource, and making no payments and being denied access to the resource.

Assuming the individual is risk averse (i.e., marginal utility of income is diminishing), it is straightforward to show that the willingness-to-pay locus is concave to the origin.[7] This locus is illustrated for one uncertain user of wildlife resources in figure 1b by *WTP*. Given the user's probabilities of being in the two states, the expected value of the first two benefit measures discussed (S_H, S_L) and (*OP*, *OP*) are illustrated by *J* and *K*, respectively.[8] In this case, option value (the difference between *OP* and $E[S]$) is positive. However, alternative specifications of the willingness-to-pay locus could yield positive, negative, or even zero option value.[9]

Estimating maximum willingness to pay involves specifying the contingent-payment pair on *WTP* which has the maximum expected value. This combination is known as the fair-bet point and, in general, is distinct from both the surplus and option price combinations.[10] That is, neither $E[S]$ nor *OP* correctly estimates maximum willingness to pay. A necessary condition for maximizing the expected value of contingent payments (i.e., maximizing $E[C] = \eta_H \cdot C_H + \eta_L \cdot C_L$) subject to (4) is that the marginal utility of income be equated across states. This is illustrated in figure 1a by points *e* and *f*, where the marginal utilities in the high- and low-quality states are equal and expected utility is $\bar{U}$.[11] The fair-bet payment

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[6] More fundamentally, the restrictive requirements of notification, exclusion, and enforceability will almost invariably obviate possibilities for either state-independent or state-dependent payments in the context of wildlife valuation. That is, no payment scheme would be implementable. Under these circumstances, selection of a benefit measure will have to be judged by other criteria.

[7] The slope of the willingness-to-pay locus is given by

$$dC_F/dC_L = \frac{\eta_H}{\eta_L} \frac{\partial U_H \partial Y}{\partial U_L \partial Y}.$$

[8] The expected value of a contingent-payment plan *C* is given by

$$E(C) = \eta_H \cdot C_H + \eta_L \cdot C_L.$$

Thus, a line through any contingent-payment combination with slope of $-\eta_S/\eta_L$ gives all combinations with the same expected value.

[9] The original and more general demonstration of this result was developed by Schmalensee. A heuristic exposition is given in Bishop.

[10] This point is convincingly made in Graham's analysis for situations involving individual (as contrasted with collective) risk. Individual risk in this context refers to state probabilities varying across potential users, a case that frequently applies to demanders of wildlife resources facing quality uncertainty. Collective risk requires that state probabilities be invariant across users.

[11] In figure 1a, it is assumed that marginal utility in the high-quality state (MU_H) is greater than marginal utility in the low-

in the high-quality state (F_H) and low-quality state (F_L) occur at point L on the WTP locus in figure 1b, where the slope of the individual's willingness-to-pay locus equals the ratio of the state probabilities. A comparison of points K, J, and M illustrates the central analytic result: the expected value of the fair-bet point $E[F]$, not OP or $E[S]$, is the theoretically preferred benefit measure for an uncertain user of wildlife resources. In general, use of OP or $E[S]$, regardless of their relative magnitudes, will result in underestimation of maximum willingness to pay for wildlife resources.[12]

In summary, three alternative benefit measures have been discussed for a demander of wildlife resources who is uncertain about recreation quality. When OV is positive, a case which Freeman has argued will occur frequently, $E[S] < OP < E[F]$. That is, in the theoretical framework of risk-averse expected utility maximization, $E[F]$ is the preferred welfare measure of resource benefits and the use of either $E[S]$ or OP will result in an underestimation bias.

Some users of wildlife resources may be indifferent to quality uncertainty, their willingness to pay is unaffected by uncertainty and any use is a "successful" or high-quality recreational experience. Examples include hunters who are indifferent about bagging their limit or bird watchers who enjoy observing wildlife generally as opposed to wanting to observe a particular rare bird. For these individuals there is, in effect, no quality uncertainty, and the appropriate benefit measure is compensating variation (consumer surplus). In figure 1a, if the user is certain of enjoying the high-quality state, then S_H becomes the monetary measure of user benefits.

Alternative Benefit Measures: Empirical Considerations

Theoretical considerations outlined in the previous section suggest that for users of a wildlife recreation area who view recreation quality as certain (for them there is no success vs. failure dichotomy), consumer surplus (as an approximation for compensating variation) is the appropriate measure of site benefits. Additionally, for risk-averse demanders who are maximizing expected utility and view recreation quality as uncertain, $E[F]$ is the appropriate benefit measure. In empirical applications, both types of resource demanders will utilize a given recreation area and accurate benefit estimation will require distinguishing between the two groups.

The necessity for making such a distinction is illustrated by the results of a pretest questionnaire administered to members of the American Birding Association (ABA). The questionnaire was designed to measure benefits attributable to the use of the Cave Creek Recreation Area in southeastern Arizona. Cave Creek is an internationally known bird watching area, known for sighting of such rare species as the Coppery-Tailed Trogan and the Golden Crown Kinglet. Twenty-five ABA members familiar with the Cave Creek area volunteered to participate in the pretest. Of this group, 16% indicated that they view recreation quality at Cave Creek as certain since a large variety of birds can invariably be sighted, and the sighting of one particular bird does not significantly affect their willingness to pay. For the remaining 84%, the value of a visit to Cave Creek would normally be predicated upon the possibility of sighting a specific rare bird. Thus, use of the area was viewed as enjoyable if no sighting occurred but much more enjoyable if a sighting did occur.[13] For this group, recreation quality was uncertain and CS estimates of benefits would be inappropriate.

Types of Wildlife Recreationists

The complexity inherent in wildlife benefit valuations is illustrated in figure 2. In addition to distinctions between certain and uncertain demanders of wildlife resources, the user population is further divided with respect to expected utility-maximizing behavior and atti-

quality state (MU_L) over the relevant income range. If $MU_H = MU_L$ over this range, then the fair-bet and OP points coincide. This outcome was inferred by Freeman when it was assumed that indirect utility was strongly separable in income. However, Plummer later showed that such an assumption implies implausible conditions for the individual's direct utility function.

[12] Option price represents maximum willingness to pay, subject to the constraint that payments are identical in all states of the world. The fair-bet point, as an unconstrained measure of willingness to pay, has an expected value greater than or equal to option price.

[13] This type of state dependence of utility functions is illustrated in figure 1a. Note that utility levels are higher in the low-quality state when access to wildlife resources is available (U_L) than in the no access state ($\bar{U}$) and are highest with both access and high-quality states (U_H).

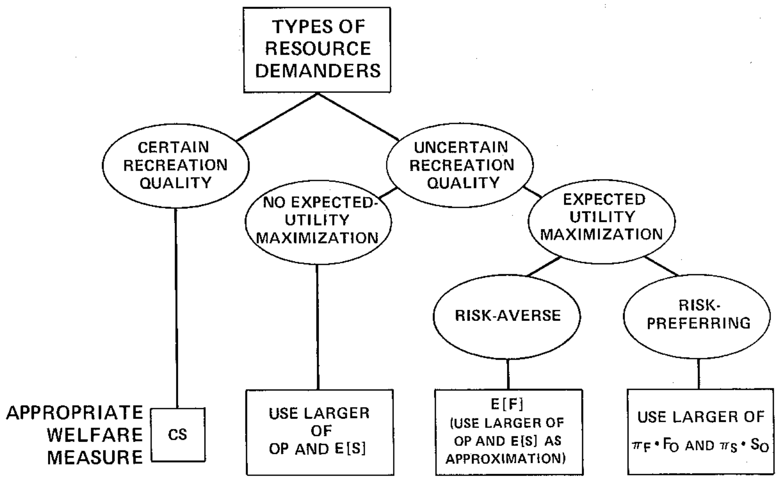

Figure 2. Types of resource demanders and corresponding benefit measures

tudes towards risk. The applicability of consumer surplus, expected consumer surplus, option price, and expected value of fair-bet contingency payments as alternative measures of value is directly dependent upon individual attitudes toward three factors: uncertainty, expected utility maximization, and risk.

For users who are uncertain about recreation quality, benefit estimation requires an evaluation of alternative contingent payment contracts for which the user would voluntarily contract to insure supply. In the context of the Cave Creek estimation, four contingent contracts were proposed to assess the nature of an individual's *WTP* curve. Participants in the pretest were asked to state their maximum willingness to pay for entrance to Cave Creek to have the opportunity to view a rare bird under four conditions: (*a*) no refund of payment regardless of sighting success (i.e., the *OP* contract), (*b*) full refund of payment if no sighting occurs (i.e., the contract on the *WTP* locus which intersects the horizontal axis in figure 1b, (*c*) refund of one-half of the payment if no sighting occurs (i.e., a contract on the *WTP* curve between the previous two contracts), and (*d*) full refund of payment if a successful sighting occurs (i.e., the contingent contract on the *WTP* locus which intersects the vertical axis in figure 1b.)[14]

Based on an evaluation of responses, 32% of the respondents were risk-averse expected utility maximizers, 8% were risk-preferring expected utility maximizers, and 44% were not expected utility maximizers (i.e., contingent-payment responses were inconsistent with either risk-averse or risk-preferring expected utility theory), with the remaining 16% viewing recreation quality as certain. The percentage breakdown of resource demander types in the Cave Creek valuation is not, of course, intended to be representative. Use of a larger sample size, a different wildlife recreation area, or an alternative user population would significantly affect category percentages. However, the Cave Creek results demonstrate that wildlife valuation projects will involve a user population with varying attitudes toward uncertainty, expected utility maximization, and risk. The appropriateness of the *CS*, *E*[*S*], *OP*, and *E*[*F*] measures of benefits depends directly on which of the four resource demander groups illustrated in figure 2 is being evaluated.[15]

[14] Responses by risk-averse expected utility maximizers were expected to generate *WTP* curves concave to the origin while risk-preferring responses would generate convex to the origin *WTP* curves. In addition to evaluating contingent-payment responses directly, attitudes toward risk were measured by asking each respondent if they would accept a fair wager (i.e., a bet with a 50% chance of winning) involving the amount of their *OP* willingness to pay. Rejection of this fair wager was taken as additional evidence of risk aversion, while acceptance gave an additional indication of risk-preferring behavior over this incremental range of income.

[15] This finding is consistent with Freeman (1984), Smith (1982) and others discussing benefit measurement under demand uncertainty, who note that the appropriateness of alternative benefit measures is dependent on the nature of uncertainty confronting a potential user and recommend that empirical studies identify the source of demand uncertainty as a preliminary step in the valuation process.

Risk-Averse Expected Utility Maximization

Responses to contingent-payment questions by users in this demander category generate concave to the origin *WTP* curves. In this case, identifying $E[F]$ is the correct benefit procedure. To carefully estimate $E[F]$ would involve asking enough contingent-payment questions to enable a statistically significant regression analysis to be conducted on the relationship between C_H and C_L along the *WTP* locus. As a practical matter, such a procedure would prove onerous to the respondent and impractical for the analyst. The difference between $E[F]$ and $E[S]$, option premium, will depend on the degree of risk aversion, state probabilities, income, and the magnitude of consumer surpluses in both quality states, so it is difficult to specify a priori the degree to which expected surplus estimates will result in undervaluation. Since $E[F]$ is always the largest of the three measures discussed, a compromise procedure would be to report the larger of aggregate *OP* or $E[S]$ for the user population and conduct a sensitivity analysis to determine if refinement of this estimate is likely to result in different policy prescriptions. Aggregate *OP* or $E[S]$ is a minimum value estimate and if this exceeds the value of the wildlife recreation area in proposed alternative uses (e.g., mining, timber production), then further efforts to estimate the correct benefit measure (aggregate E[F]) for policy purposes are unnecessary.

Risk-Preferring Expected Utility Maximization

Responses to contingent-payment questions by this demander group generate convex to the origin *WTP* curves.[16] In this case, the contract which satisfies the necessary conditions for $E[F]$ represents a minimum benefit estimate and does not apply. Similarly, *OP* is an inappropriate measure of site benefits since either the expected value of a full-refund contract in the success state or the expected value of a full-refund contract in the failure state will reflect the maximum payment a risk-preferring user would be willing to make to insure supply.

[16] Responses by risk-neutral expected utility maximizers generate linear *WTP* curves. For purposes of benefit measurement, risk-neutral responses are treated as a special case of risk-preferring since an identical estimation procedure applies.

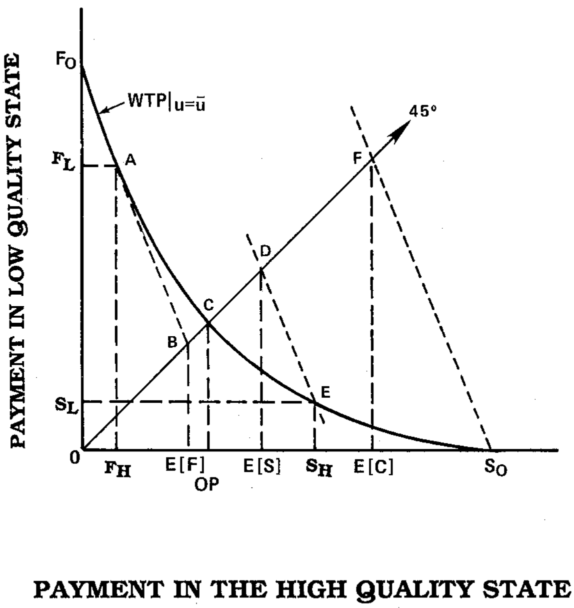

Figure 3. Risk-preferring expected utility maximization and alternative benefit measures

These estimation relationships are illustrated in figure 3. For this demander of wildlife resources, the contract which satisfies the $E[F]$ necessary conditions occurs at A with contingent payments (F_H, F_L) in the high- and low-quality states, respectively. Given state probabilities, the expected value of this contract is reflected by point B on the 45-degree line. The *OP* benefit measure is reflected by point C, and the $E[S]$ value, given consumer surplus contingent payments of (S_H, S_L) in the high- and low-quality states, respectively, is identified by point D. However, the contingent contract with the largest expected value in this example is (S_O, O), the full-refund in the failure state agreement. That is, use of any conventional contingent contract results in undervaluation of site benefits. The correct welfare measure is the larger of the expected values of the two full-refund contracts, (S_O, O) or (O, F_O).

A three-step procedure is required to estimate site benefits for uncertain, risk-preferring users who are maximizing expected utility. First, state probabilities must be assigned or estimated. Second, *WTP* under both full-refund policies must be solicited. Third, the larger of $\eta_L \cdot F_O$ and $\eta_H \cdot S_O$ is then reported as the measure of demander benefits.

Uncertain Recreation Quality without Expected Utility Maximization

Responses to contingent-payment questions by this uncertain demander group generate *WTP* curves that are inconsistent with either risk-averse or risk-preferring expected utility maximization. A variety of explanations may apply in these circumstances in accounting for inconsistency with anticipated theoretical responses: (*a*) confusion generated by lack of familiarity with contingent-payment plans, (*b*) risk-averse behavior over one range of payments coupled with risk-preferring behavior over remaining payments,[17] or (*c*) use of a heuristic other than expected utility maximization for assessing uncertainty.[18]

A pragmatic procedure for individuals whose responses are inconsistent with expected utility maximization would be to report the larger of the two conventional benefit measures, $E[S]$ or OP. The advantages of this procedure are that contingent-payment questions concerning these contracts can be readily formulated and comprehended, responses can be easily related to responses by other demander groups, and the expense of in-depth personal interviews to fully assess the nature of inconsistent responses can be avoided. However, there is no theoretical reason to believe that $E[S]$ or OP represents maximum willingness to pay for this user group. Economic benefit estimation under uncertainty is based on expected utility maximization, and there is little theoretical guidance on how to proceed when this behavioral model does not apply.

Summary and Implications for Further Research

Demanders of wildlife resources can be divided into four groups (summarized in fig. 2) based on their attitudes toward recreation-quality uncertainty, expected utility maximization, and risk. Accurate benefit estimation requires differentiation of the user population with respect to these characteristics since the appropriate welfare measure varies by demander group. In particular, the following guidelines are proposed. First, for resource demanders who view recreation quality as certain, consumer surplus (as an approximation for compensating variation) is the appropriate measure of user benefits. Second, for uncertain, risk-averse demanders of wildlife resources who are maximizing expected utility, the expected value of the fair-bet contingent contract accurately reflects user's maximum willingness to pay to insure supply. For this group of resource demanders, the larger of option price or expected consumer surplus can be used as a lower bound on user benefits and further refined if sensitivity analysis suggests that policy recommendations require it. Third, for uncertain, risk-preferring resource demanders who are maximizing expected utility, no conventional benefit measure applies. For this user group, the larger of the expected values of full-refund contingent contracts is the correct benefit measure and the three-step estimation procedure discussed above applies. Finally, for uncertain demanders who are not maximizing expected utility, the larger of option price and expected consumer surplus becomes the pragmatic estimate of user benefits.

Differentiating wildlife resource demanders with respect to uncertainty, expected utility maximization and risk, so that the appropriate benefit measures may be applied, will increase the accuracy and theoretical defensibility of benefit estimates. However, implementation of these recommendations will require extensive modification of traditional contingent valuation instruments. In particular, data collection instruments will require a dendritic design that keys on responses to initial screening questions concerning recreation quality. Respondents who view recreation quality as certain will branch to traditional questions designed to estimate consumer surplus. Respondents who view recreation quality as uncertain will branch to a series of contingent-payment questions. These questions should be designed to estimate option price, expected consumer surplus, and maximum willingness to pay using alternative refund policies. Additionally, since the user population will typically consist of distinct subgroups, sample

[17] Tversky and Kahneman reported on an extensive body of experimental results in which individuals evidenced risk-averse behavior over income levels above their endowment and risk-preferring behavior over income levels below their endowment.

[18] The empirical evidence on expected-utility-maximization behavior is not uniformly reassuring. Shoemaker notes several conceptual drawbacks and empirical counter examples to expected utility theory in his survey article on the subject. Kahneman and Tversky have proposed prospect theory as an alternative specification of behavior under risk, a specification largely consistent with evidence from the experimental psychology literature.

representativeness will require increased sample size and minimization of potential response bias. That is, to generalize from the questionnaire sample to the user population as a whole, each subgroup must be represented in sufficient numbers to insure statistical significance, and a high response rate is necessary to minimize the possibility of one particular subgroup being underrepresented because of an unusually low rate of reponse.

While incorporating these refinements into contingent valuation procedures will not be costless, the additional expense incurred appears modest relative to the total cost of contingent valuation processes and will yield more accurate and theoretically defensible benefit estimates. This study also suggests that research efforts need to be directed at benefit estimation for individuals who are not expected utility maximizers since the benefit measures analyzed in this study are not necessarily appropriate for this group.

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The Required Rate of Return for Publicly Held Agricultural Equity: An Arbitrage Pricing Theory Approach

Robert A. Collins

Recent interest in equity financing for commercial agriculture has created the need to reexamine the required rate of return for agricultural equity. The required rates of return for ten publicly held firms with agricultural operations are examined with arbitrage pricing theory. The results suggest that the required rate of return for this group of firms is similar to the required rate of return for an average share of stock.

Key words: arbitrage pricing theory, cost of capital, equity financing.

The well-documented growth in farm size and associated increases in capital intensity over the last thirty-five years have created difficult financing demands for the U.S. agricultural sector. The growth in real assets has exceeded the rate at which equity could be generated within the sector, resulting in increases in debt financing.[1] This secular trend has created interest in mechanisms for attracting external equity into the farm sector (Boehlje; Fiske, Batte, and Lee; Collins and Bourn; Moore; Penson) to give production agriculture a choice between debt and equity financing. Several institutional structures that would allow a proprietary farm to gain access to Wall Street equity have been proposed. One proposal (Collins and Bourn) suggests that a publicly traded real estate investment trust (REIT) could form limited partnership agreements with individual commercial farms. If the REIT provided a certain amount of financing in exchange for a share of the farm's income, a formal financial intermediary would exist to channel equity financing from Wall Street to commercial farms. A mechanism allowing a proprietary farm to attract outside equity financing could allow for orderly firm growth with less financial risk and thus less turmoil in future difficult times. The rate of return that investors would require to provide equity financing to agriculture depends on the risks associated with agricultural investments and how these risks affect the risk of a well-diversified portfolio. This study briefly evaluates previous studies of the required rate of return for agricultural investments and estimates the required rate of return for ten publicly held firms with arbitrage pricing theory (APT).

The first attempt to evaluate the required rate of return for an agricultural investment was Barry's pioneering capital-asset-pricing-model (CAPM) study of farmland. He regressed the earnings and capital gains from farmland on an index and found very little systematic risk. From this, he concluded that the required rate of return to hold farmland in a well-diversified portfolio is only slightly above the riskless rate. He cautioned, however, that the thin markets for land and the illiquidity of the investment could cause the required rate of return to be higher than what the CAPM suggested.

The problem of estimating a liquidity premium is substantial. Even though economic theory suggests that a premium for both illiquidity and systematic risk should exist, the measurement of liquidity and the associated premium is generally neglected in the literature. Since the market models (CAPM, APT)

[1] Some of the secular increase in the use of debt undoubtedly reflects the choice to borrow more and reinvest less rather than the sheer force of expansion. These choices may have been affected by a general change in attitudes toward debt as well as by incentives of government agricultural policy (see Gabriel and Baker, Collins).

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Table 1. Regression Model

Dependent Variable: Earnings per Share of S & P 500 Firms
Independent Variable: S & P 500 Index

Coefficient	Standard Error	t	H_0
$\hat{\alpha} = 1.77$	$\sigma_\alpha = 0.32836$	$t = 5.38$	(H_0: $\alpha = 0$)
$\hat{\beta} = 0.01$	$\sigma_\beta = 0.00254$	$t = -388$	(H_0: $\beta = 1$)

Note: $R^2 = .333$.

make no provision for illiquidity, the required rate of return for agricultural investments must be estimated from the behavior of agricultural investments that are liquid, that is, publicly traded.

The problem with this approach is that there are so few publicly traded agricultural investments that are available for evaluation. Additionally, the available sample is not a very representative cross section of American agriculture. This would tempt one to follow Barry's approach and evaluate aggregate agricultural income. However sensible this approach may appear, it neglects an important aspect of asset pricing. The systematic risk(s) of publicly traded ownership interests in assets may be very different from the systematic variation in the income stream of the assets. This occurs because the systematic effects in the capitalization of income by equity markets are ignored. This may be thought of as the systematic capital gains and losses caused by the changes in the average price-earnings ratio (P/E).

This problem may be demonstrated by examination of a broad-based market index like the Standard and Poors (S&P) 500 composite index. The returns to the index have by definition a systematic risk (β) of one. However, if income only is examined, a very different result obtains. This method was tested by regressing the average earnings per share for the S&P 500 stocks on the S&P 500 index. Earnings per share include recognized capital gain income and operating income. Results of this regression using quarterly data from 1975 through 1985 are shown in table 1. With an estimated β of 0.01, it is apparent that some systematic risk is being missed. The hypothesis test for H_0:$\beta = 1$ yields a t-value of -388.5. This creates substantial doubt that risk premia for equities may be reliably estimated from systematic variation in income alone. This occurs because the effects of systematic movements in the average P/E are not considered.

In addition, empirical applications of the CAPM have been criticized because empirical tests have produced results inconsistent with theory. There have been many of these studies, a few of which are Blume and Friend; Black, Jensen, and Scholes; Miller and Scholes; Blume and Husick; and Fama and Macbeth. Nearly all of the studies agree that the intercept of the security market line is greater than the riskless rate and that the slope is less than the market risk premium. Roll pointed out that previous tests of the CAPM were really tests of *ex post* mean-variance efficiency of the market index. He also raised serious questions about the potential for empirically testing the CAPM. All of this created support for APT, which is more general and apparently testable (see Dybvig and Ross, Shankin).

Arbitrage Pricing Theory

The APT model requires no assumptions about the form of the distribution of the return to assets, and no specific form is required for investors' utility functions. The market portfolio is not required to be efficient and, indeed, is not considered. It allows multiple factors to influence asset returns as the multiple index CAPM does but focuses on unanticipated shifts in the factors. APT has also survived well from ten years of empirical scrutiny (Roll and Ross; Chen; Bower, Bower, and Logue) Comparisons with the CAPM generally favor APT, and evaluations of testing procedures have not established major flaws. (See Dhrymes, Friend, and Gultekin 1984 for a critical perspective.) As a result of these theoretical and empirical advantages, APT is emerging as a preferred model of asset pricing under risk.

The number of factors that may affect the price of individual assets is very large. Most of these factors, however, are unique to particular firms or groups of firms, and their effects may be diversified away. Assuming these idiosyncratic effects can be eliminated by costless diversification, they will not affect the return required by investors. Factors that cause well-diversified portfolios to vary in value are called systematic factors and provide the basis for market risk premiums. It is assumed that investors incorporate expectations of shifts of the systematic factors into their expectations of each asset's return, and only the unanticipated changes in the systematic factors affect asset prices. Therefore, the basic assumption of APT may be stated as follows:

$$(1) \qquad \tilde{R}_i = E(\tilde{R}_i) + \beta_i' F + \tilde{\epsilon}_i,$$

where $\underset{N\times 1}{\tilde{F}}$ is a random vector of systematic factors with zero means, $\underset{N\times 1}{\beta_i}$ is a vector of sensitivity coefficients to the systematic factors for asset i, $\underset{1\times 1}{\tilde{\epsilon}_i}$ is the return to idiosyncratic factors for asset i, ($E[\epsilon] = 0$), E is the expectations operator, and the random rate of return to asset i is ($\tilde{R}_i$).

It is presumed that self-interested, risk-averse investors will be constantly vigilant for opportunities to improve their risk-return position by revising their portfolios or by forming "arbitrage portfolios." (A clear and simple explanation of this process may be found in Roll and Ross 1984.) Assets with high expected returns relative to their systematic risk will be bought, driving their price up and expected return down, and the opposite will occur for "overpriced" stocks. Assuming that investors are greedy and risk averse and that arbitrage portfolios having no risk and requiring no wealth can earn no return,[2] Ross shows that in equilibrium the expected (and required) return on asset i will be

$$(2) \qquad E(\tilde{R}_i) = R_F + \lambda'\beta,$$

where $\underset{N\times 1}{\lambda}$ is a vector of market "prices" of risk associated with the systematic factors.

The primary weakness of the model is that it is not clear what the relevant, i.e., priced, factors are. Roll and Ross (1980) and Chen, Roll, and Ross suggest that the real economic factors that are priced include unanticipated changes in (*a*) inflation, (*b*) industrial production, (*c*) risk premiums, and (*d*) the slope of the yield curve. Because of the obvious data problems of observing unanticipated shifts, empirical APT studies continue to use factor analysis to estimate the factors. Following Roll and Ross (1980) and Bower, Bower, and Logue (1982, 1984), this study uses a four-factor model. The factor analysis model produces a set of four orthogonal factor scores that best explain security returns.

Table 2. Publicly Held Agricultural Firms and Primary Products

Firm	Primary Agricultural Product
Cagles, Inc.	Poultry
Castle and Cooke, Inc.	Fruits, vegetables
Friona Ind., Inc.	Cattle
Katy Ind., Inc.	Shrimp, cheese
Newhall Land and Farming	Wheat, cotton, sugar beets, alfalfa
Orange-Co., Inc.	Citrus
San Carlos, Inc.	Sugar
Southeastern Public Service	Miscellaneous crops
Sun City Ind., Inc.	Shell eggs
Tejon Ranch Co.	Livestock, farming

Estimation of APT Parameters

The data used to estimate the factor analysis model were daily returns from all stocks continuously listed on the New York and American stock exchanges in the period 1 January 1978 through 31 December 1984. These firms and their primary products are shown in table 2. The daily returns data were collected for the 1,771 stocks meeting this sample criterion from the Center for Research in Security Prices (CRSP) tape. Monthly returns were calculated for each stock by finding the geometric mean of the daily returns. To reduce noise, the 1,761 nonagricultural stocks were grouped into 57 equally weighted portfolios of about 30 stocks each from similar industries.[3] The 84 monthly observations of the 57 portfolios were then factor analyzed with a four-factor iterated

[2] Other assumptions require the usual conditions of homogenous beliefs and frictionless markets along with bounded expectations and the existence of a type-*B* agent with nonnegligible wealth.

[3] This procedure and other estimation practices are carefully evaluated in Bower, Bower, and Logue (1982).

Table 3. Estimated APT Reaction Coefficients for Ten Publicly Held Agricultural Firms

Firm	Estimated APT Coefficients				R^2
	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	
Cagles, Inc.	0.0296*	−0.0460*	−0.0300*	0.0283*	.17
Castle and Cooke, Inc.	0.0479*	−0.0006	0.0062	0.0147*	.33
Friona Ind., Inc.	0.0488*	−0.0006	−0.0023	0.0039	.22
Katy Ind., Inc.	0.0813*	−0.0251*	0.0068	0.0097	.41
Newhall Land and Farming	0.0583*	−0.0114	0.0100	−0.0082	.31
Orange-Co., Inc.	0.0445*	0.0226*	0.0084	0.0005	.13
San Carlos, Inc.	0.0836*	−0.0199	0.0520*	0.0579*	.30
Southeastern Public Service	0.0183*	−0.0118	0.0105	0.0053	.07
Sun City Ind., Inc.	0.0638*	−0.0132	−0.0083	0.0116	.29
Tejon Ranch Co.	0.0653*	−0.0016	0.0389*	−0.0118	.24

Note: Asterisk indicates significant at 10% level.

principal factor analysis model. The factor scores fit the data well, with an average communality coefficient of 0.868 over the 57 portfolios. The APT coefficients were estimated in the standard fashion (Bower, Bower, and Logue 1982, 1984) from these four common factors:

$$\delta_{1t}, \ldots, \delta_{4t}, \qquad t = 1, \ldots, 84.$$

First, the sensitivity of each of the fifty-seven portfolios to the common factors was estimated with time-series regressions. Each portfolio's return (R_{it}) was regressed on the factor scores ($\delta_{1t}, \ldots, \delta_{4t}$) from the factor analysis (57 regressions, 84 observations each):

$$(3) \qquad R_{it} = \beta_{i0} + \beta_{i1}\delta_{1t} + \ldots + \beta_{i4}\delta_{4t} + \epsilon_{it} \qquad i = 1, \ldots, 57.$$

The estimated values of the beta coefficients in equation (3) were then used to estimate the lambda coefficients in equation (2) with cross-sectional regressions. The portfolio returns for each month were regressed on their estimated betas from the time-series regressions (84 regressions, 57 observations each):

$$(4) \qquad R_{it} = \lambda_t + \lambda_{1t}\hat{\beta}_{i1} + \ldots + \lambda_{4t}\hat{\beta}_{i4} + \eta_{it} \qquad t = 1, \ldots, 84.$$

The lambdas are the marginal effect of the betas on the required return of the portfolio, and η is the error term.

The average value of each of the lambda parameters over the eighty-four regressions was used as the value for the APT model.[4] The annualized estimated APT equation for the market model was

$$(5) \qquad E(r_i) = 0.0557 + 2.998\hat{\beta}_1 + 1.271\hat{\beta}_2 - 1.268\hat{\beta}_3 - 0.448\hat{\beta}_4.$$

Estimates of the required rate of return for the ten agricultural firms required estimating their reaction coefficients. The APT coefficients were estimated by regressing the returns from each of the ten agricultural firms (A_{jt}) on the factor scores:

$$(6) \qquad A_{jt} = \beta_{j0} + \beta_{j1}\delta_{1t} + \beta_{j2}\delta_{2t} + \beta_{j3}\delta_{3t} + \beta_{j4}\delta_{4t} + \gamma_{jt}, \; j = 1, \ldots, 10.$$

The results of these equations are shown in table 3.

Estimates of the required rate of return for the ten agricultural firms are shown in table

Table 4. Estimated Required Rates of Return for Ten Publicly Held Companies with Agricultural Assets

Company	Required Return APT (%)
Cagles, Inc.	11.1
Castle and Cooke, Inc.	18.4
Friona Ind., Inc.	20.2
Katy Ind., Inc.	25.5
Newhall Land and Farming	20.7
Orange-Co., Inc.	20.7
San Carlos, Inc.	18.9
Southeastern Public Service	11.0
Sun City Ind., Inc.	23.5
Tejon Ranch Co.	20.5
Mean	19.05

[4] This is the current state of the art in estimating APT models. See Roll and Ross (1980); Chen; and Bower, Bower, and Logue (1982, 1984).

4.[5] Estimates of the required rate of return for each firm were derived by substituting estimated reaction coefficients from equation into market equation (5). These estimates are shown in table 4. The average required rate of return for the ten sample firms was 19.05%. The required rate of return for the average share over the sample period was slightly higher at 20.8%. It does not appear that the required return for the average of the firms is different in any important sense from all stocks. The APT estimates are higher than the CAPM estimates in Collins and Bourn because of differences in the riskless rate and the expected market return. In Collins and Bourn, estimates of current values were used. When estimates from the sample period are used, the average CAPM estimate for the ten firms is higher than the APT estimates at 21.25%. These estimates are much higher than Barry's estimates for farmland because systematic risk from changes in the P/E ratio are considered. Presumably, equity interests in illiquid agricultural assets with the same systematic risks would be higher because of the liquidity premium.

Summary and Conclusions

This paper estimates with arbitrage pricing theory the return investors require to hold publicly traded equity investments in ten agricultural firms and compares these estimates to conventional capital-asset-pricing-model estimates. The model indicates a much higher required rate of return than previously estimated with annual data for farmland, but APT estimates are slightly lower than CAPM estimates for publicly held agricultural stocks. Based on the small number of firms available for study, there is no compelling reason to believe that the required rate of return for publicly traded agricultural equities is any different than for other publicly traded equity investments. This suggests that the investment community regards the effect of agricultural investments on the riskiness of a well-diversified portfolio to be neither excessive nor minimal and stands ready to provide equity capital for agriculture if provided reasonable terms and a viable institutional structure. Given that investors' requirements are accurately reflected by this small sample of firms and the prevailing rates of return to equity in commercial agriculture, the average farm could not sell equity at par to an agricultural equity pool unless investors expected substantial capital gains. It appears that investors might be interested only in the small proportion of commercial farms that are very well managed and highly successful.

[5] Since the first factor has the largest coefficient [equation (5)] and estimates of β_1 differ substantially between firms (table 3), it appears that the first factor is responsible for a large part of the difference in required rate of return between firms.

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