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Stephen D. Reiling and Mark W. Anderson

LIFE SCIENCES AND AGRICULTURE EXPERIMENT STATION
UNIVERSITY OF MAINE AT ORONO

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THE RELEVANCE OF OPTION VALUE IN BENEFIT-COST ANALYSIS

Stephen D. Reiling and Mark W. Anderson*

INTRODUCTION

Option value has been the subject of considerable debate in the economic literature since it was first introduced by Weisbrod [1964]. This debate is of importance because of its implications to public investment decision criteria, particularly when they are applied to the trade-off between the preservation and development of a natural resource or area. These decisions often produce heated public discussion, such as those surrounding the Tellico Dam snail darter controversy and the construction of a hydroelectric dam in the Hell's Canyon.

It has been argued that option value should be included in benefit/cost calculations to measure the "true" costs of development. That is, option value should be an addition to the negative benefits associated with development or, conversely, a positive addition to preservation benefits. Inclusion of option value in benefit/cost calculations would result in more conservative investment decisions by reducing the benefit/cost ratio of many development projects. Hence, it provides a theoretical justification for arguing against many development projects on the grounds of economic efficiency, which is the cornerstone of public investment criteria.

While the conceptual importance of option value seemed clear to the early writers on the subject, operationalization of the concept through measurement has never occurred. Measurement has only been addressed at a theoretical level. The central issue revolves around the difference between option value and expected consumer's surplus. At least one writer argued that the two concepts were one and the same, while others have "shown" that option value is greater than or less than expected consumer's surplus. All in all, this debate has raised questions about the validity and importance of the concept. Some writers have abandoned it while others have continued to defend it.

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We have two objectives in this report. The first is to review the concept of option value and determine the conditions that are necessary for its existence. This is a necessary prerequisite to the second objective, which is to examine the literature related to its measurement and draw conclusions about the importance and relevance of the concept.

In essence, this publication represents a review and a critical re-evaluation of the literature dealing with option value. This literature is rich and dynamic, and provides a fascinating sequence of articles, comments, and rebuttals. Re-evaluation of the concept requires a rather comprehensive review of this literature, which is something that has not been provided to date. The literature review is also important because the work of some authors has been systematically overlooked in the course of the debate. As a result of this oversight, the original formulation of the concept continues to be cited in the literature [see, for example, Freeman 1979] even though its practical significance is doubtful. Considerable confusion has also arisen between option value and the newer concept of an "irreversibility effect" (see below). This "irreversibility effect" has been called quasi-option value and even the "true option value." The discussion in this paper is limited to Weisbrod's original concept as it evolved, which we feel should be termed option value. Other distinct concepts should be given different names in order to prevent confusion.

THE NATURE OF OPTION VALUE

The initial formulation of option value was developed by Weisbrod [1964] in the form of "option demand." He observed that individual consumption goods may possess public good attributes. The public good characteristic stems from the existence of "option demand" or the willingness of rational "economic men" to pay for the option of consuming the good or service at some time in the future.

The concept can be best illustrated with an example. To follow Weisbrod, we can envisage a privately owned park encompassing a unique resource (such as Sequoia National Park) and the owner exercises perfect price discrimination. In addition, there are no externalities that distort the allocative decision. Under these conditions, if revenues collected by a perfectly discriminating monopolist fall short of costs,

"... allocative efficiency considerations would indicate "closing" the park, assuming that private and social rates of discount are equal" [Weisbrod 1964, p. 472]. However, Weisbrod argued that because the owner is unable to charge potential users who value the option to use the park in the future, this private decision may be inefficient from society's perspective. There are, in essence, external economies of current production that result in the free rider effect commonly associated with collective goods. "In the interests of economic efficiency, it would be desirable to keep the firm in business if the total of fees potentially collectable from current consumers and fees potentially collectable from prospective future consumers -- including those who, in fact, will not become consumers -- are adequate to cover costs" [Weisbrod 1964, p. 473].

Whenever the firm's expected revenue (exclusive of option revenue) exceeds expected costs, the option demand of people who may use the park in the future is always satisfied. That is, provision of the good or service satisfies the public good aspect reflected by option demand. Since part of the firm's output has public good characteristics, a public subsidy may be justified on efficiency grounds when one considers the willingness to pay of consumers who may never visit the site but who still value the option to visit in the future. Subsidization is *obviously only necessary in the case of the "sub-marginal" producer* whose expected revenue from actual visitors does not cover costs. If revenues plus the willingness to pay for the option are less than costs, a subsidy would not be justified and efficiency criteria would indicate that the firm should shut down.

Weisbrod indicated that option demand exists for all goods. However, he set forth two conditions that must exist for option demand to be "significant." These are: 1) infrequency and uncertainty of purchase, and 2) very high costs of increasing production once it has been curtailed.[1/] Weisbrod argued that frequently-purchased goods (and hence a high degree of certainty associated with their purchase) for

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[1/] Actually, a third condition is that the good or service in question is nonstorable. That is, it is not possible to purchase the commodity now and store it for later consumption [Weisbrod 1964, p. 472].

which output expansion is less costly will have insignificant option value. So the difference between private goods with significant option demand and those without is a matter of degree, not of kind.

Weisbrod's original exposition did not explicitly focus on its impact on public investment criteria. Instead, it illustrated the potential existence of option demand for all private (market and non-market) goods. However, its implications for public resource development projects are obvious. If a development project under consideration results in the destruction of a natural environment, the potential revenue or value of that environment to current users would underestimate the "true" value. The potential revenue that non-users would be willing to pay to retain the option to use the area in the future should be included to reflect the "true" value of the natural environment. Krutilla [1967] was one of the first writers to illustrate this point.

The notion that option value may exist for all goods could be important in attempts to operationalize the concept of option value for use in public investment decisions. The decision concerning which benefits are lost or gained in terms of option value would require a determination of whether the purchase (or use) of the commodity (or resource) was infrequent enough and its output expansion costly enough to warrant the addition of an option value to the calculation. Recognizing that an option demand exists for all commodities, the chore becomes one of determining whether this demand is of significant value.

The existence of option value for all goods and services raises another question relative to benefit/cost analysis not generally confronted in the literature. If there is an option value attached to natural resources destroyed by a project, is there not also an option value attached to the output of that project? Again, the problem becomes one of determining whether this value is significant.

The first reaction to Weisbrod's formulation of option demand came from Long [1967]. His comment focused on two issues: 1) the conditions required for option value to exist, and 2) the relationship between option value and consumer's surplus. With regard to the first, he suggests that infrequency of purchase is irrelevant and that indivisibility and heterogeneity of the commodity or resource are the conditions that produce option demand. "If the product is divisible and sold under competitive conditions, the market will give the right allocation without any government subsidy for option value ... Option value ... is only of importance for ... a commodity for which there is no good substitute" [Long 1967, p. 352]. Hence, uniqueness of the product or resource is a necessary condition for Long's interpretation of option demand.

Examination of the examples used by Weisbrod to illustrate the nature of option value suggests that he implicitly acknowledged the importance of uniqueness as a condition for option demand to be significant. For example, the park example discussed above explicitly assumed that the park contained a unique resource large Sequoia trees. His other examples, hospitals and urban transit systems, both imply a substantial degree of uniqueness. In fact, there may not be any substitutes available for the services provided by either of these facilities in many communities. Hence, it seems that uniqueness is an important condition for the presence of a significant option demand. That is, option value is positively related to the level of uniqueness of the product or resource. In terms of resource development projects, unique natural resource environments that would be destroyed by development would have a high option value whereas non-unique environments would not. Likewise, project outputs would produce significant option demand only if they are unique.

Long also disagreed with Weisbrod's other necessary condition for option value: "Weisbrod's conditions on costs (of increasing production once it has been curtailed) has nothing to do with the problem; it simply says that it is important to make correct decisions when the costs of reversing wrong ones are large" [Long 1967, p. 352]. Therefore, uniqueness (and, presumably, non-storability) are the only conditions necessary for the existence of option value according to Long.

Long also addressed the distinction between option value and consumer's surplus. Weisbrod's analysis indicated that option value was an additional value that was separate and distinct from consumer's surplus. For example, option value was separate from and in addition to the potential revenue that could be collected from users by a perfectly discriminating monopolist. The latter revenue, by definition, captures all consumer's surplus. But it fails to capture the revenue that potential users would pay for options to consume the product in the future, i.e., the option value.

Long [1967, p. 351] challenged this contention and argued that "option value is the unrecognized son of that old goat, consumer's surplus." Hence, "option value must be used in place of and not in addition to ... consumer's surplus"

Although Weisbrod did not respond to Long's comments, Lindsay [1964] defended Weisbrod's position on this latter point. Lindsay reemphasized the condition of uncertainty and compared option value to an insurance premium. "In the case of option demand, what is desired to be purchased is relief from the uncertainty that capacity or stocks will be insufficient to satisfy a later demand" [Lindsay 1967, p. 345]. He concludes that option value is different than consumer's surplus since the former exists for goods consumed in the uncertain future and the latter pertains to the certain present. The implicit conclusion is that option value is separate from, and in addition to, consumer's surplus.

Lindsay's reference to uncertainty is somewhat different than Weisbrod's in that Lindsay emphasizes uncertainty of future supply while Weisbrod emphasizes uncertainty of future demand or purchase. We believe this distinction is important and view uncertainty of purchase as the critical condition for the existence of option value. If an individual knows for certain that he will not demand the good in the future, he would not be willing to pay anything for the option, regardless of the degree of supply uncertainty.[2/] In addition, if a person knows that he will demand the good in the future, the appropriate measure of his potential loss due to supply uncertainty is the reduction

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[2/] That person may have an "existence demand," however. Existence demand represents the value of the good to a person even though he or she will never purchase it. It represents the increase in utility that people receive from knowing that something exists even though they never will consume the good. Existence demand is distinct from option demand.

in his expected consumer's surplus. Therefore, we believe that uncertainty of purchase rather than uncertainty of supply is a critical condition for the presence of option value.

Although supply uncertainty is neither a necessary nor sufficient condition for option value, it seems to be related to the concept in two ways. First, a high level of supply uncertainty may induce potential users to accurately articulate their option value and contribute revenue in the hope of insuring future provision of the good. That is, a high degree of supply uncertainty would jeopardize their free rider position. On the other hand, one would hypothesize that potential users would discount their value of the option in proportion to the level of supply uncertainty. The degree to which potential users believe that the sum of revenue raised from the sale of options would not be sufficient to guarantee future provision would influence their value of the option. This suggests that supply uncertainty may influence the magnitude of option value as well as the willingness of potential users to articulate their option value. But it is not a necessary condition for the existence of option value.

A summary of the above discussion may be useful. Option demand (or value) can be defined as the amount a consumer who is not currently consuming the good would be willing to pay to retain the option to purchase the good at the prevailing price at some time in the future. Whether or not the consumer ever exercises the option is irrelevant so long as he is willing to pay a positive sum of money for the option. We believe that four conditions must exist for option demand to be significant: 1) uncertainty of purchase, 2) nonstorability of the good, 3) a unique quality of the good (no good substitutes exist), and 4) the cost of increasing (recommencing) production once it has been curtailed (stopped) is extremely high.

With regard to the last condition, we support Weisbrod rather than Long. If this condition did not exist, occasional demanders of the product could be accommodated without extreme difficulty and there would be no need for potential users to purchase an option. We also disagree with Long's contention that option value is nothing more than expected consumer's surplus. Under conditions of demand certainty, option value and expected consumer's surplus are identical. But this ignores the basic premise of demand uncertainty that underlies the concept of option value. We do believe, however, that a relationship exists between option value and expected consumer's surplus. This will be discussed in detail in the next section.

THE MEASUREMENT OF OPTION VALUE

The exchange between Long and Lindsay set the stage for the subsequent debate about the relationship between option value and consumer's surplus. Some writers argued that option value was separate and in addition to consumer's surplus, while others contended that the concepts were the same. Different authors adopted different conceptual frameworks to "prove" their point. The most striking change in the debate is that subsequent writers presented more formal and more rigorous tools to analyze the issue.

Byerlee's Utility Function Approach

Byerlee [1971] was the first to formalize the discussion by introducing a von Neumann-Morgenstern utility function framework. This formalized the uncertainty of future purchase aspects of option value emphasized by Lindsay and Weisbrod. Byerlee assumed that the purchase of an option assures future availability of the good to the owner of the option while non-purchase precludes future consumption. We will briefly summarize Byerlee's analysis and then raise a question regarding the appropriateness of the formulation.

Byerlee presents the following pay-off matrix for the purchase of an option for good X with the consumer's income, Y. The quantity of X and Y are measured relative to the consumer's present position and -y represents the income given up to purchase the option.

	Desires to Purchase X (S_1)	Does Not Desire to Purchase X (S_2)
$P(S_i)$	P	(1-P)
Purchase Option (A_1)	(X, y)	(0, y)
Does Not Purchase Option (A_2)	(0, 0)	(0, 0)

The option value problem can be stated in terms of the pay-off matrix: "find the maximum amount (of income), y_d, that the decision maker would pay for the option of consuming X. That is, we require the value of y that makes the decision maker indifferent between alternatives A_1 and A_2" [Byerlee 1971, p. 524]. In other words, we want to solve for the variable y_d such that the utility associated with alternatives A_1 and A_2 are equal:

$$U\ (A_1) \quad U\ (A_2) \tag{1}$$

$$\text{where } U\ (A_1) \quad p\ U\ (X, \quad y_d) + (1 \quad p)\ U\ (0, \quad y_d)$$

$$\text{and } \quad U\ (A_2) = p\ U\ (0,\ 0) + (1 \quad p)\ U\ (0,\ 0)$$

Byerlee then defines the utility of the consumer's present position to be zero. That is: $U\ (0,\ 0) \quad 0$. This provides the reference point for comparing other situations with the present position in the von Neumann-Morgenstern framework. This allows us to rewrite equation (1) as:

$$p\ U\ (X, \quad y_d) + (1 \quad p)\ U\ (0, \quad y_d) = 0 \tag{2}$$

Two conclusions can be drawn from equation (2). First, by assuming that (a) the only price the consumer has to pay to consume the good is the price of the option, and (b) the consumer is certain that he will consume the good in the future ($p \quad 1$), equation (2) reduces to:

$$U\ (X, \quad y_d) \quad 0 \tag{3}$$

But, by definition, the consumer's surplus (y_c) is equal to:

$$U\ (X, \quad y_c) \quad 0 \tag{4}$$

Therefore, $y_d \quad y_c$. That is, under conditions of certainty of future purchase, option value and consumer's surplus are identical.

Second, if we assume that the decision maker must pay a price of y_c to purchase good X under conditions of uncertainty, equation (2) becomes:

$$P\ U\ (X, \quad y_c \quad y_d) + (1 \quad p)\ U\ (0,\ y_d) \quad 0 \tag{5}$$

Since $U\ (X, \quad y_c) \quad 0$, clearly $y_d \quad 0$. "That is, for a perfectly discriminating monopolist charging a price that extracts all consumer's surplus, option demand is zero" [Byerlee 1971, p. 525]. This result contradicts the conclusion of Weisbrod and others that option demand was in addition to the revenue that could be collected by a perfectly discriminating monopolist.[3/]

[3/] We challenge Byerlee's conclusion below.

Byerlee [1971, pp. 526-527] also draws other conclusions about the relationships between expected consumer's surplus and option value. These relationships vary with changes in degree of risk aversion adopted by the consumer and the shape (marginal rate of substitution) of the consumer's indifference curve for income and good X. He concludes that risk averse individuals would "discount uncertain gains and pay less than the expected consumer surplus, and not something additional as Lindsay claims." He also suggests that expected consumer's surplus and option demand should be dropped from the economists' vocabulary and be replaced with a broader definition of consumer's surplus: the amount of "money a consumer would pay for the right to buy at the current price something that he is now buying or may buy in the future."

Clearly, Byerlee's article focuses on the nature of the measurement problem associated with option demand. His results contradict those of earlier writers, especially Weisbrod and Lindsay who argue that option value is in addition to the revenue received by a perfectly discriminating monopolist. Although Byerlee's formulation has not been criticized in the literature, we do not believe his approach "proves" that option value is zero when a person pays a price for the good that is equal to his consumer's surplus.

Our challenge stems from the utilities assigned to the cells of the pay-off matrix; specifically, we disagree with the utility assigned to the A_2 S_1 cell of the matrix. Byerlee contends that if a person does not purchase an option but later desires to purchase the good, the individual suffers no utility loss. That is, his level of utility is the same as it was at the time he was faced with the decision of whether or not to purchase the option. In effect, this removes all the incentive the individual would have to purchase the option. We question the validity of this reasoning. It seems to us that the individual would suffer a utility loss (relative to the level at the time the decision on the option is made) if he chooses to not purchase the option but then decides at a future time he would like to purchase the good. That is, the level of utility associated with the A_2 S_1 cell should be less than utility associated with the A_2 S_2 cell. In the former case the consumer would like to purchase the good and in the latter he does not want to purchase the good. We are, however, uncertain about the appropriate measure of the magnitude of this loss. Perhaps it should be equal to the expected value of the consumer's surplus $E(y_c)$.

If our criticism is correct, it has significant implications regarding the conclusions of Byerlee. For example, U (A_2) would not be equal to zero; and, the right hand side of Equation (2) would not be equal to zero. Therefore, one could not conclude that option value was equal to consumer's surplus under conditions of certainty or that option value is equal to zero when the good is sold by a perfectly discriminating monopolist.

The latter point is important since Byerlee contradicts Weisbrod. We believe that if the A_2 S_1 cell of the matrix accurately reflected the utility loss the individual would suffer in that situation, it would be possible for option value to exist over and above the revenue of the discriminating monopolist. Even a perfectly discriminating monopolist can only collect revenue from those who actually purchase the good. Potential users who desire to hedge against the possible utility loss associated with not being allowed to consume the good in the future may pay a positive sum for the option. This revenue would be in addition to the perfectly discriminating revenue received from current users. Hence, we do not believe Byerlee has adequately demonstrated that Weisbrod erred in his original argument that option value is an addition to consumer's surplus in the presence of uncertainty of demand.

Positive Option Value: Circchetti and Freeman Proof

Cicchetti and Freeman [1971] were next to address the relationship between option value and expected consumer's surplus.[4/] We believe that our criticism of Byerlee's formulation was recognized by Cicchetti and Freeman [1971, p. 529] and that it provided a major motivation for their response:

[4/]This article is a condensation of a more complete treatment of the subject by Krutilla, Cicchetti, Freeman, and Russell (Krutilla, et al., 1972). However, we will follow the convention in the literature, particularly that from RFF, and consider the Cicchetti and Freeman article as the primary reference. The major difference between the two is that the more comprehensive article presents the proof in terms of compensating and equivalent measures, whereas the shorter one presents only the compensating variation argument. This made no difference in the authors' conclusions.

> "[Byerlee] concludes that expected consumer's surplus could exceed the maximum option price a risk averter would pay, i.e., that pure option value could be negative. His model includes the loss that an individual would experience if he purchased the option but did not exercise it ... However. a second kind of loss is also relevant, the loss associated with not purchasing the option and later demanding the good but finding it not to be available. This is a reflection of supply uncertainty as well"[5/] (emphasis added).

Hence, they also question Byerlee's contention that there is no loss in utility if a person does not purchase the option, but later demands the good and is not allowed to purchase it.

Given this background, Cicchetti and Freeman [1971, p. 530] state their objective unambiguously:

> "We will show that where there is uncertainty and individuals are risk averse, a perfectly discriminating monopolist who can exclude those who do not pay the option in advance will maximize the present value of his stream of revenues by selling options to purchase the good in the future at specified price, and that these revenues will be greater than the present value of the expected consumer surpluses. The difference is option value."[6/]

Cicchetti and Freeman adopt a framework in which the selling monopolist has a two-part pricing scheme. In the first part the

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5/ We prefer to refer to this as access uncertainty rather than supply uncertainty. Option value can exist even in the case of certainty of future supply (or availability) if only those persons who purchase the option have the right to access or consumption.

6/ Note that, for option value to be positive, the "specified price" at which the good is sold to option holders is not the perfectly discriminating price. If an individual knew that the price charged to consume the good in the future would extract his entire consumer's surplus, the option to retain (or obtain) the right to purchase the good would have zero value. This point was illustrated by Zeckhauser [1969].

monopolist sells options for future use and charges each purchaser the maximum he is willing to pay for the option. In the second part, the monopolist charges a predetermined price when option holders desire access to the good. The question to be addressed is whether the maximum price the consumer will pay for the option (OP) is ever greater than the expected value of his consumer's surplus, E(CS). This difference, if any, is defined as option value (OV):

$$OV \quad OP \quad E(CS) \tag{6}$$

In terms of equation (6), Cicchetti and Freeman "show" that option value is positive; that is, the price a consumer will pay for the option is greater than the expected value of his consumer's surplus, given uncertainty of future demand and high risk averse behavior by the consumer.

They begin their analysis by looking at the special case of certainty of future demand, i.e., the probability of future demand, P (d), is equal to one. They resurrect Byerlee's conclusion by showing that option price is equal to consumer's surplus under this special condition. That is:

$$OP = E(CS) = CS$$

$$\text{when } P(d) \quad 1$$

Therefore:

$$OV \quad 0$$

This confirms Weisbrod's original contention that uncertainty of future demand is a necessary condition for the existence of option value.

The second, and major part of their analysis is less straight-forward and less convincing. Figure 1 presents a three-move, eight-outcome game tree that Cicchetti and Freeman use to accommodate both access and demand uncertainty in their model. The utilities associated with each of these outcomes can be ranked, as long as we confine ourselves to assuming that the consumer either demands or does not demand the good in the future. Table 1 shows what these two rankings would be. The logic behind these rankings should be clear. For example, U_5 is the utility associated with the free rider phenomenon. Here the consumer does not buy the option, demands the good, and has it supplied. Cicchetti and Freeman assume this outcome has a probability of zero (0),

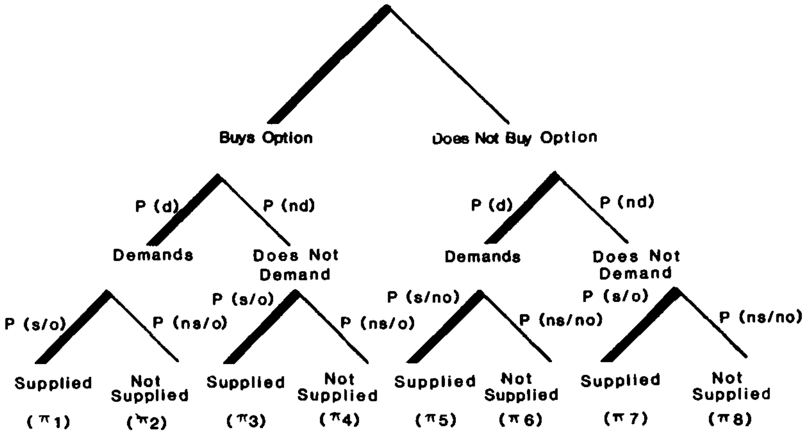


TABLE 1. Rankings of Utilities Associated with Game Tree Outcomes

Consumer Demands	
Rank	Utility
1	U_5
2	U_1
3	U_6
4	U_2

Consumer Does Not Demand	
Rank	Utility
1	U_7 U_8*
2	
3	U_3 U_4*
4	

*Assumes the future is compressed into a single time period.

as does the converse outcome, U_2, where the consumer purchases the option, demands the good and the good is not supplied. They go on to present two indifference mappings to represent the utilities associated with these outcomes. Only one of the two mappings will exist for each consumer depending on whether or not he demands the good. They then devise a method to make the two indifference mappings commensurable:

> "For any level of disposable income (e.g., Y_0), if the individual did not demand the good he would choose a consumption point on the Y axis and experience a certain level of utility (e.g., U_8); if he were to demand the good (assuming that is available [to the individual]), he would choose a tangency point on the budget line associated with that point, and experience a given level of utility (e.g., U_5). We <u>assume</u> that the alternative outcomes have the same utility. Thus, U_8 U_5" [Cicchetti and Freeman, p. 534; emphasis added].

We believe that the stated assumption requires the reader to make a giant leap of faith. Although there is nothing to prevent the equality of U_5 and U_8, there certainly is nothing in their analysis that guarantees it either. Hence, we question the validity of the Cicchetti and Freeman framework and view their conclusion that option value is greater than zero as being suspect. As Henry [1974, p. 90] noted: "It appears that their (Cicchetti and Freeman's) result depends crucially on the very particular way in which they 'make their utilities commensurable' " In fact, intuitively, it makes little sense that outcomes 5 and 8 yield the same utility. U_5 is the "free rider" outcome described above, whereas U_8 derives from the consumer not purchasing the option, not demanding the good, and not having it supplied. For the utilities of these two outcomes (U_5 and U_8) to be equal is as illogical as Byerlee's conclusion that not purchasing an option, and later demanding the good and not having it supplied, entails no loss in utility.

Despite these problems, there were some other points made by Cicchetti and Freeman that should be noted. First of all, they did deal explicitly with the question of supply uncertainty, although not in a detailed manner in the short article. They asserted that supply uncertainty, even once the option is purchased, will reduce the option price, but as long as the probability of supply is greater than that of no supply, option value will still be positive.

Second, Cicchetti and Freeman's [1971, p. 539] conclusions led them to believe that uncertainty of demand can cause significant distortion of the allocative process in public investments. "Thus, where there is a large number of low probability demanders, omission of the option value benefit and a consideration only of the consumer surplus of the expected number of users would result in a significant understatement of benefits."

The Cicchetti-Freeman analysis is also useful for illustrating the importance of the assumption of risk aversion to the existence of option value. Risk aversion implies a diminishing marginal utility of income. Hence, the utility function, $U \quad f(y)$, is concave from below. Concavity of the utility function is a sufficient condition for option value to be positive in the Cicchetti-Freeman model. That is, the maximum option price will exceed the expected value of consumer's surplus if the individual acts in a risk averse manner. On the other hand, if the individual is risk neutral (utility function is linear), option value is equal to zero. Finally, if the individual is a risk seeker or gambler, the maximum option price is less than the expected value of consumer's surplus and option value is negative.

We can summarize the conclusions reached by Byerlee and Cicchetti and Freeman based on their respective analyses. Some of their conclusions are consistent. For example, both agree that option value is zero under conditions of demand certainty and when the seller charges the perfectly discriminating price to all consumers who decide to purchase the good. They also agree that option value is zero (negative) if consumers are risk neutral (seekers). The major differences between the two approaches is that Cicchetti and Freeman believe option value is always positive when individuals are risk averse and face uncertainty of future demand. Byerlee's analysis indicates that option value may be $\gtreqless 0$ under these same conditions. The sign and magnitude of option value depend upon the shape of the individual's indifference curves and the degree of risk aversion. But we can add risk aversion to the list of necessary conditions required for option value to be other than zero.

Both of the articles explain and clarify the nature of option value and its relationship to consumer's surplus. However, we believe that both analyses contain flaws that prevent general acceptance of either set of conclusions. These flaws are at least partially due to the methodological framework used in the respective analyses. Both frameworks lack an acceptable technique to describe and/or equate the utility levels associated with the alternatives of purchasing and not purchasing an option.

Two major challenges to the Cicchetti and Freeman article have been presented. Schmalensee [1972] challenged the conclusion that option value is always positive; Arrow and Lind [1970] on the other hand, questioned the validity of the assumption of risk aversion when estimating project benefits from a social viewpoint. We will consider each of these below.

Schmalensee Challenge

Schmalensee adopted a state-preference framework of analysis that included the following elements:

N--possible states or situations that may occur in the future

π_i--known probability of state i occurring

P--a state in which price of commodity X is so high that it is generally not available

P*--a state in which price of commodity X is such that it is generally available

S_i--consumer surplus for state i if P* prevails instead of P

OP--option price individuals would be willing to pay to assure that P* prevails (in all states) in the future

Y_i--conditional incomes in state i

U^i--utility associated with state i and income Y_i

U_y^i--marginal utility of income in state i

Given this model, option value is defined as

$$OV = OP - \Sigma\pi_i S_i$$

Schmalensee posited some basic conditions regarding risk aversion in this model by assuming that the individual will accept neither fair nor unfair bets; instead, the consumer will only accept gambles that are biased in his favor. From this he concluded that a sufficient condition for the individual to be risk averse at some point $([Y_i], P)$ is ($[Y_i]$ refers to a vector of possible future incomes):

$$U_y^i\ (Y_i, P) = U_y^j\ (Y_j, P)$$

That is, the individual is risk averse at the stated point only if the marginal utilities of all future incomes are equal at that point. This statement serves to relate the conditional utility functions to each other.

Schmalensee illustrated that option value may be positive or negative using both equivalent and compensating measures of consumer surplus; below, we develop the argument for only the equivalent variation measure. The equivalent variation consumer's surplus (SE_i) is the amount the individual would have to be compensated to be indifferent between P and P* in state i. More formally for a given sta i:

$$U^i\ (Y_i, P^*) \quad U^i\ (Y_i + SE_i, P)\ (i = 1, \ldots N) \tag{7}$$

Equivalent option price (OPE) can be defined as the amount of income that would have to be given to the consumer in every state in order to make him indifferent between P and P*.

$$\sum_{i=1}^{N} \pi_i U^i (Y_i, P^*) \quad \sum_{i=1}^{N} \pi_i U^i\ (Y_i + OPE, P) \tag{8}$$

and equivalent option value (OVE) is:

$$OVE = OPE \quad \sum_{i\ \ 1}^{N} \pi_i SE_i \tag{9}$$

With these definitions, Schmalensee shows that OVE is non-positive when the individual is risk averse at the state (Y_i + OPE, P) if the equivalent variations (SE_i) are not the same for all states. If they are the same for all states, then OVE   0: i.e.,

$$\sum_{i=1}^{N} \pi_i U^i (Y_i + SE_i, P) \quad \sum_{i=1}^{N} \pi_i U^i\ (Y_i + OPE, P) \tag{10}$$

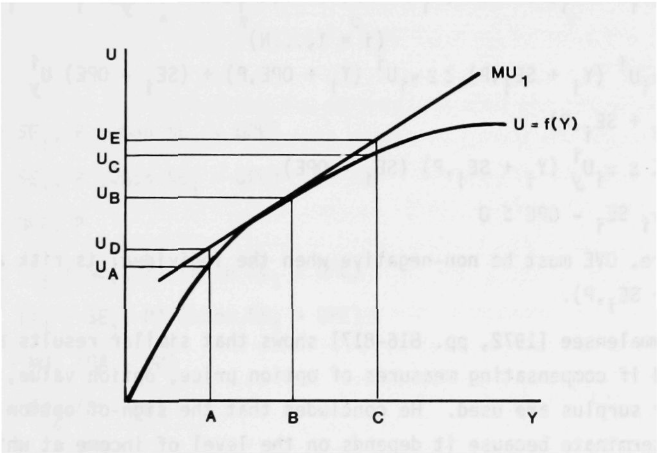
Given the more realistic assumption that the SE_i are not the same for all states and the utility functions are concave, Schmalensee construct the following inequality:

$$U^i (Y_i + SE_i, P) \leq U^i (Y_i + OPE, P) + (SE_i - OPE)\, U^i_y (Y_i + OPE, P) \tag{11}$$

$$(i \quad 1, \ldots N)$$

This inequality is graphically illustrated in Figure 2. MU_1 is the marginal utility of income at $(Y_i + OPE, P)$. For the individual to be risk averse by Schmalensee's definition, MU_1 must be the marginal utility at all levels of income; hence we can project MU_1 back to the point $(Y_1 + SE_i, P)$ and see that $U_A \lesseqgtr U_D$, where U_A and U_D represent the left hand and right hand side of inequality (11), respectively. The same result is obtained if SE_i is greater than OPE. That is, $U_E \gtreqless U_C$. Substituting (11) into (10) yields:

$$\Sigma\, \pi_i U^i (Y_i + SE_i, P) \leq \Sigma\, \pi_i U^i (Y_i + OPE, P) + \Sigma\, \pi_i U^i_y (Y_i + OPE, P)$$
$$(SE_i \quad OPE, P) \tag{12}$$



A $\quad Y_i + SE_i$, P (when $SE_i < OPE$)
C = $Y_i + SE_i$, P (when $SE_i > OPE$)
B $\quad Y_i + OPE$, P
$MU_1 \quad U^i_y (Y_i + OPE, P)$
$U_A \leq U_B + MU_1 (OA \quad OB)$ and $U_C \leq U_B + MU_1 (OC \quad OB)$
$\therefore U_A \leq U_D$ and $U_C \leq U_E$

Figure 2. Case Where Equivalent Option Value is Non-Positive

Substituting (10) into (12) and substracting like terms from each side yields:

$$0 \leq \Sigma\ \pi_i U_y^i\ (Y_i + OPE,P)\ (SE_i \quad OPE,P) \qquad (13)$$

Since U_y^i $(Y_i \quad OPE,P)$ is constant for all i because of the definition of risk aversion:

$$\sum_{i=1}^{N} \pi_i\ SE_i \quad OPE \geq 0 \qquad (14)$$

Therefore, the equivalent option value (OVE) must be non-positive in the case where the individual is risk averse at (Y + OPE,P).

The same approach is used to demonstrate that the equivalent option value is non-negative when the individual is risk averse at income level $(Y_i + SE_i,P)$. See Figure 3. Algebraically, the result is obtained in the same manner as above:

$$U^i(Y_i + SE_i,P) \geq U^i\ (Y_i + OPE,P) + (SE_i \quad OPE)\ U_y^i\ (Y_i + SE_i,P) \qquad (15)$$

$$(i = 1,\ldots N)$$

$$\Sigma\ \pi_i U^i\ (Y_i + SE_i,P) \geq \Sigma\ \pi_i U^i\ (Y_i + OPE,P) + (SE_i \quad OPE)\ U_y^i$$

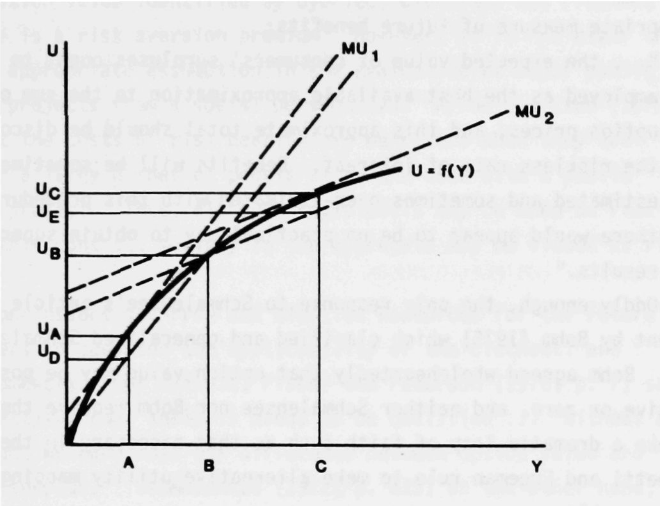
$$(Y_i + SE_i,P) \qquad (16)$$

$$0 \geq \Sigma\ \pi_i U_y^i\ (Y_i + SE_i,P)\ (SE_i \quad OPE) \qquad (17)$$

$$\Sigma\ \pi_i\ SE_i \quad OPE \leq 0 \qquad (18)$$

Therefore, OVE must be non-negative when the individual is risk averse at $(Y_i + SE_i,P)$.

Schmalensee [1972, pp. 816-817] shows that similar results are obtained if compensating measures of option price, option value, and consumer surplus are used. He concludes that the sign of option value is indeterminate because it depends on the level of income at which the individual is risk averse. The implication of this conclusion is that the relative social risk of development versus preservation is indeterminate. Hence, Schmalensee's conclusions are consistent with our earlier observation that option value can exist for project outputs as well as preserved environments. The sign of option value associated with preservation depends on the relative riskiness of preservation versus the riskiness of development.



A $Y_i + SE_i, P$ (when $SE_i < OPE$)

$C = Y_i + SE_i, P$ (when $SE_i > OPE$)

$B = Y_i + OPE, P$

MU_1 $U_y^i (Y_i + SE_i, P)$ (when $SE_i < OPE$)

MU_2 $U_y^i (Y_i + SE_i, P)$ (when $SE_i > OPE$)

$U_A \geq U_B + MU_1 (OA \quad OB)$

$U_C \geq U_B + MU_2 (OC - OB)$

$U_A \geq U_D$

$U_C \geq U_E$

Figure 3. Case Where Equivalent Option Value is Non-Negative

Since the sign of option value is indeterminate, Schmalensee [1972, p. 823] advocates the use of expected consumer's surplus as the appropriate measure of future benefits:

> "... the expected value of consumers' surpluses ought to be employed as the best available approximation to the sum of their option prices, and this approximate total should be discounted at the riskless rate of interest. Benefits will be sometimes under-estimated and sometimes over-estimated with this procedure, but there would appear to be no practical way to obtain superior results."

Oddly enough, the only response to Schmalensee's article was a comment by Bohm [1975] which clarified and generalized Schmalensee's work. Bohm agreed wholeheartedly that option value may be positive, negative or zero, and neither Schmalensee nor Bohm require the reader to make a dramatic leap of faith such as that necessary in the Cicchetti and Freeman rule to make alternative utility mappings commensurable.

Schmalensee and Bohm do, however, disagree over the practical application of the theory of option value. Schmalensee, as we noted, believed that expected consumer surplus should be used in benefit/cost calculations, while Bohm [1975, p. 736] says that, because we do not know the probabilities associated with future preference states for each consumer, that expected consumer surplus cannot be determined. "The option price is, therefore, the _only_ measure of the benefit side of the investment that can conceivably be determined -- by sales of access rights, by interviews, by government "introspection," or other imperfect approaches."

The question arises, given a world of ideal institutions, yet a continued lack of clairvoyance of the future, which of these two measures would we like to obtain to measure the future benefits of a resource. Clearly option price is the superior measure of benefits in the abstract, as long as we are unable to completely eliminate both supply and demand uncertainty and we accept the assumption of risk aversion. Expected consumer surplus will, as Schmalensee pointed out, tend to either over-estimate or under-estimate benefits.

The Nature of Risk Aversion: The Arrow and Lind Contribution

The option value identified by Byerlee, Cicchetti and Freeman, and Schmalensee is a risk aversion premium. However, it is not clear that this is an appropriate assumption in the evaluation of major public investment projects from a social perspective. Arrow and Lind [1970] showed that the costs of risk bearing are near zero when they are spread over a large number of people as in the case with a public investment project. Thus, although individuals may be seen as risk averse in this context, society in the aggregate may be viewed as risk neutral.

The conclusions of Arrow and Lind led Resources for the Future staff members to question the applicability of the Cicchetti and Freeman framework. For example, Fisher and Peterson [1976, p. 7] said, "The Cicchetti-Freeman analysis needs to be qualified ... Without a risk premium, we have lost our difference between option value and consumers' surplus." Schmalensee [1972, p. 823] on the other hand, argued that the Arrow and Lind conclusion does not undermine his assumptions of risk aversion for public investment projects where benefit/cost analysis would normally be employed. This is because, "... benefits from government investments typically accrue mainly to a fraction of society, and risk-spreading arguments have little force in such cases." The nature of risk as it relates to public investment remains a moot point.

CONCLUSIONS

Remains of Option Value

What can we conclude from the body of literature discussed above? Initially, Weisbrod hypothesized that option value may exist for all goods and that a positive increment of benefits must be added to expected consumer's surplus to account for those people who value the option to use the resource or product in the future. Cicchetti and Freeman presented a framework to substantiate Weisbrod's hypothesis that option value is always positive. However, we believe their analysis is flawed and, therefore, their conclusions are unwarranted. Schmalensee and Bohm, on the other hand, provide a convincing argument that option value may be positive, negative or equal to zero even though the two writers disagree on the practical conclusions for measuring social benefits. Schmalensee favors the measurement of expected consumer's surplus as a proxy for social benefits whereas Bohm favors measurement and use of option price. We believe that option price is the best measure of benefits for an individual in society. However, we agree with Schmalensee that we are better able to measure expected consumer's surplus than option price.

Option value is inevitably related to the problem of market allocation of collective goods. In many instances this problem is due to institutions rather than the nature of the commodity. Simply stated, society is not willing to accept methods that exclude some people from use of collective goods. For example, the use of many national and state parks could be limited to those possessing options which had to be purchased in advance. The sale of these options by the government and allowing their subsequent market transfer would better indicate the value individuals place upon the right to use these resources in the future. The only barrier that exists to the measurement of the option price of such outdoor recreational experiences is an institutional one. Clearly we have little reason to desire that the government act as a price discriminating monopolist in the allocation of outdoor recreational resources. But many such goods that presumably have an option value in excess of consumer surplus could be evaluated in this way if it were considered socially desirable.

Even if society was willing to accept methods that would allow the measurement of option price, the Arrow and Lind analysis suggests that the resulting values would not be appropriate for use in benefit/cost calculations. Option value is a premium that assumes individuals are risk averse. Arrow and Lind show that risk is inversely related to the number of people who enjoy the benefits and who pay the costs. Since costs and benefits are often spread over many people in society the risk encountered by any one individual is very small. The total risk to society also decreases as risks are spread over more people. Thus, Arrow and Lind argue that society should assume a risk neutral posture in estimating social benefits and costs. This eliminates the risk aversion condition required for option value to be non-zero. However, Schmalensee argues that the benefits of public investments are often localized and thus these risk-spreading arguments are not relevant. Thus, it appears we are faced with a dilemma. On one hand, option price seems to be the theoretically superior measure of benefits for an individual in society who exhibits risk-averse behavior. On the other hand, risk aversion may not be an appropriate assumption when calculating social benefits. Furthermore, we are pessimistic about our ability to effectively determine the sign and magnitude of option value even if option value was an appropriate measure to include in benefit/cost studies. Therefore, we are inclined to conclude that adjustments for option value are not possible and/or warranted in the calculation of social benefits and costs.

Beyond Pure Option Value

If the demise of pure option value in benefit/cost studies has not yet been publicly acknowledged, there is tacit recognition of this fact in the development of the concept of "quasi-option value." Arrow and Fisher [1974], Fisher and Krutilla [1974], and Henry [1974] all pointed out that when a development of a natural resource entails irreversibilities and/or information from the present period will lead to a better understanding of the costs and benefits of future development the, "... net benefits from developing the area are reduced and, broadly speaking, less of the area should be developed" [Arrow and Fisher 1974, p. 314]. As Fisher and Krutilla [1974, p. 97] said a "... conservative policy toward development is indicated in such a circumstance." Hence, the irreversible nature of some decisions and the potential for improved information for making these decisions in the future are sufficient for the existence of quasi-option value.

Irreversibility, with the exception of the loss of species, is a relative concept and is a function of time and price. There is a threshold of cost and time beyond which we consider the action to be irreversible, even though in strictest terms the action is reversible. Thus, the destruction of a redwood forest is different from the destruction of the last redwood seed. But we consider the forest's destruction as irreversible for all practical purposes. This extreme case is easy to agree upon on practical grounds. There are certainly less extreme cases in which the distinction between reversible and irreversible actions is less clear to all.

A detailed discussion of quasi-option value will not be presented here. However, it is clearly related to the option value identified by Weisbrod. For example, Weisbrod's condition that the prohibitively high cost of reinitiating production of a good or resource once it has been stopped can be construed to be equivalent to an irreversible action. Furthermore, it would seem that uniqueness of the good or resource will have an important influence on both option value and quasi-option value. However, we believe that the term "quasi-option value' has created some confusion concerning its relationship to option value. We agree with Henry [1974, p. 90] who suggests that the value associated with irreversible decisions should be labeled the "irreversibility effect" rather than quasi-option value.

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