OPTION VALUE

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The option value of a good is the amount which potential consumers of the good are prepared to pay now, to ensure that the good remains available for future purchase. Option values should be considered when making resource allocation decisions, so that efficient decisions are made. The theoretical basis of option value is described and the problems involved in the recognition, use and measurement of option value are discussed.

Option Value Background

The option value of a good is the amount which potential consumers of the good are prepared to pay now, to ensure that the good remains available for future purchase. The failure to recognize the option value component of the total value of goods can lead to inefficient allocations of resources to the production of those goods. It is particularly important that option values be considered when an irreplacecable good, such as a wilderness area, is threatened with allocation to an irreversibly destructive type of land use.

Option value was first described by Weisbrod (1964) as the value that non-users of a good place on its continued availability. It is the value of an option to purchase the good in the future.

By Weisbrod's definition, a good has an option value if some of its potential consumers hope to purchase the good in the future, even though they may never do so. These potential consumers value the continued availability of the good because it gives them the option to purchase it in the future.

Therefore, the continued availability of a good provides a community with two types of benefits, so that the total value of such goods includes two components:

1. Value to individual users.
2. Collective option value to potential consumers.

There are two main reasons why most methods for evaluating goods exclude their option values. Option values are difficult to collect, and the theoretical validity of the option value concept has not been universally accepted.

The Difficulties of Collection

The option value associated with the availability of a good cannot readily be collected by the good's seller. Two reasons are:

1. As shown later, positive option value often only exists when potential consumers are uncertain of their future demand for the good. Since many of them will probably never demand the good, their option value for the good will never be reflected in user receipts.
2. Option value is an external benefit resulting from the continued availability of a good. Consequently, the free rider problem prevents the collection of a good's option value unless supply

exclusion is possible. If exclusion can be enforced, then the good becomes unavailable to those who choose not to purchase an option to guarantee its future availability to them.

Because the option value of a good is not usually collected in most real world situations, it cannot be directly measured in money terms.

Consequently, resource allocation decisions are often made in the absence of option values, thereby increasing the probability that poor decisions will be made.

Repeating Weisbrod, option value is only important to resource allocation if, when option value is added to the user demand, it would cause a change in the level of supply. To use Weisbrod's example, consider a park owned by a discriminating monopolist whose expected future costs just exceed expected future returns (based on user charges). The owner will close the park because he does not expect to make a profit, and he will allocate his resources to a more profitable alternative, such as mining, farming or subdivision. However, if the option value placed on the continued availability of the park by the community were greater than the difference between the expected costs and returns for the park, then it would be socially desirable for the park to stay open. In this case, the inability of the park to make a money profit would be due to market failure. It would not mean that the park's resources were inefficiently allocated.

Similarly, hospitals, postal services, defence services and public transport systems often fail to make a money profit, yet are seen by the community as socially desirable ways in which to allocate some of its resources. Option value makes up a large part of the total value of services of this type. It is often least cumbersome to have such services provided by the government, so that money losses incurred by their provision can be underwritten by taxation, thereby avoiding the difficulty of collecting their option values by more direct methods.

The Difficulties of Acceptance

Like many new concepts, the existence and validity of option value has been debated in the literature (Weisbrod, 1964; Long, 1967; Lindsay, 1969; Zeckhauser, 1969; Schmalensee, 1972; Krutilla, Cicchetti, Freeman and Russel, 1972; Gallagher, 1973). The theoretical acceptability of the option value concept has been demonstrated only recently (Schmalensee, 1972; Krutilla *et al.*, 1972; Gallagher, 1973).

Long (1967) claimed that option value was no more than or less than the expected consumer's surplus, since rational people would not pay more for an option than the consumer's surplus that they expected to derive from purchasing the good. Being satisfied that option value and consumer's surplus are one and the same thing, Long then contradicted Weisbrod by pointing out that, as a consumer's certainty of demand for a good increased, so would his expected consumer's surplus (and hence option value).

Lindsay (1969) supported Weisbrod, criticizing Long on the grounds that he had ignored two of the conditions which Weisbrod had specified to be necessary for option value to exist. They are:

1. A good can only have an option value if its potential users are uncertain about their future demand for the good.

2. Option value only exists for non-storable goods whose production cannot easily be restarted or expanded once it has been stopped or curtailed.

Long had shown that option value did not exist, under conditions in which Weisbrod had never claimed that it did.

Zeckhauser (1969) explained that if the supply of a good were controlled by a price discriminating monopolist, then the option value of the good would be zero, regardless of the degree of uncertainty of potential consumers' future demand for the good. For example, a potential consumer would know that if he demanded the good in the future, the supplier would charge him the maximum amount he was willing to pay. Therefore the potential consumer would be indifferent between purchasing and forgoing the good, and would consequently place no present value on an option to ensure future availability of the good.

Krutilla *et al.* (1972), Schmalensee (1972) and Gallagher (1973) have since defined option value more rigorously, to overcome Zeckhauser's valid criticism of Weisbrod's concept. The theoretical description of option value by Krutilla *et al.* incorporates the effects of consumers' preference structures and uncertainty of demand and supply. In addition, their approach excludes the case where the good in question is subject to perfect price discrimination both now and in the future. They define option value to exist only where the perfectly discriminating monopolist who supplies the good chooses to use a two-part pricing system. This involves the purchase of an option in the present, to allow the future purchase of the good at a price which is specified in the option. With this system, price discrimination applies to the purchase of the option, but the price at which any subsequent purchase of the good can be made is fixed.

Option Value Theory

The following exposition of the theory of option value is based on that by Krutilla *et al.* (1972). It involves finding the option value placed on a good by each potential consumer. Aggregation of these individual option values would give the total option value of the good.

The development of the theory of option value was a result of the disquiet felt by some economists at the increasing rate at which irreplaceable natural assets are allocated to destructive and more profitable types of land use. Many thought that an irreplaceable natural asset must have some intangible value, making it worth more to the community than the sum of the values placed on its use by individuals. The theoretical derivation of option value has shown that this intuitive feeling was correct.

Decisions related to the allocation of natural resources often involve a choice between two alternative land uses:

1. Persistence with the present land use, so that the natural resource can continue to act as a source of benefits of both the individual and collective consumption types.
2. Allocation of the natural good to an exploitative type of land use. The new land use may cause irreversible changes in the natural resource, so that the first type of land use is no longer possible.

Option value is closely related to the concept of consumer's surplus, so the first step towards defining option value is to rigorously define consumer's surplus. Then option value can be defined so that the two concepts are mutually exclusive, to prevent double counting.

The price compensating and price equivalent measures of consumer's surplus, as defined by Hicks (1944), are appropriate measures with which to evaluate natural resources which are threatened with allocation to destructive types of land use. The price related measures of consumer's surplus show the sizes of the cash flows which are needed to make present and potential consumers indifferent between the possibility of being able to consume a finite amount of the natural resource and the possibility of not being able to consume any of the natural resource. This choice coincides with the two possible outcomes of the land use decision described previously.

Price Compensating Measure of Consumer's Surplus (CV)

The price compensating measure of consumer's surplus (CV) is the maximum price that a consumer of a good would be prepared to pay over and above the present purchase price of the good, in order to preserve his right to purchase it.

Price Equivalent Measure of Consumer's Surplus (EV)

The price equivalent measure of consumer's surplus (EV) is the size of the bribe which would be just sufficient to make a consumer of a good relinquish his right to continue to purchase it.

Hicks showed that for people with declining marginal utilities of income, the price equivalent measure is always greater than the price compensating measure of consumer's surplus. The two consumer's surpluses are equal only if a person's marginal utility of income is constant. Because CV and EV usually differ, care must be taken to choose the measure of consumer's surplus which is the more appropriate for each case that is considered.

When considering the introduction of a new good, it may be necessary to find the value that potential consumers place on its availability. This would be shown by the price compensating measure of consumer's surplus, i.e. the amount of income that potential consumers would be prepared to forgo in order to have the new good made available for purchase.

If a good is to be withdrawn, the price equivalent measure of consumer's surplus is more appropriate. It represents the amounts by which the incomes of present consumers would have to be increased in order to compensate them for the good becoming unavailable.

When considering a proposal for one good to be replaced by another, the consumer's surpluses of both goods may need to be evaluated.

Option Price (OP) and Option Value (OV)

The maximum option price of a good is defined as the price of an option at which a potential consumer is indifferent between accepting the option and not accepting it.

Option value is then defined as the difference between the maximum option price and the expected value of consumer's surplus.

$$OV = OP - \exp CS$$

There will be two different measures of option value, depending on whether the price compensating or price equivalent approach is used.

OVc = price compensating measure of option value.
OVe = price equivalent measure of option value.

To simplify the theoretical treatment of option value, it is assumed that the marginal rate of time preference is zero.

A Von Neumann-Morgenstern game tree is presented in Figure 1. It depicts the eight possible outcomes from a decision by a potential consumer to accept or reject an option. Using this game tree, the option value of a good can be found under a wide variety of conditions of supply and demand.

Let:

U_o = expected utility from accepting an option
U_{no} = expected utility from rejecting an option
U_i = utility associated with the *i*th outcome
P(D) = probability of demand
P(ND) = probability of no demand
P(S/O) = probability of supply if an option is taken
P(NS/NO) = probability of no supply if an option is not taken.

Therefore, from the game tree:

$$U_o = P(D)[U_1 . P(S/O) + U_2 . P(NS/O)] + P(ND)[U_3 . P(S/O) + U_4 . P(NS/O)] \quad (1)$$

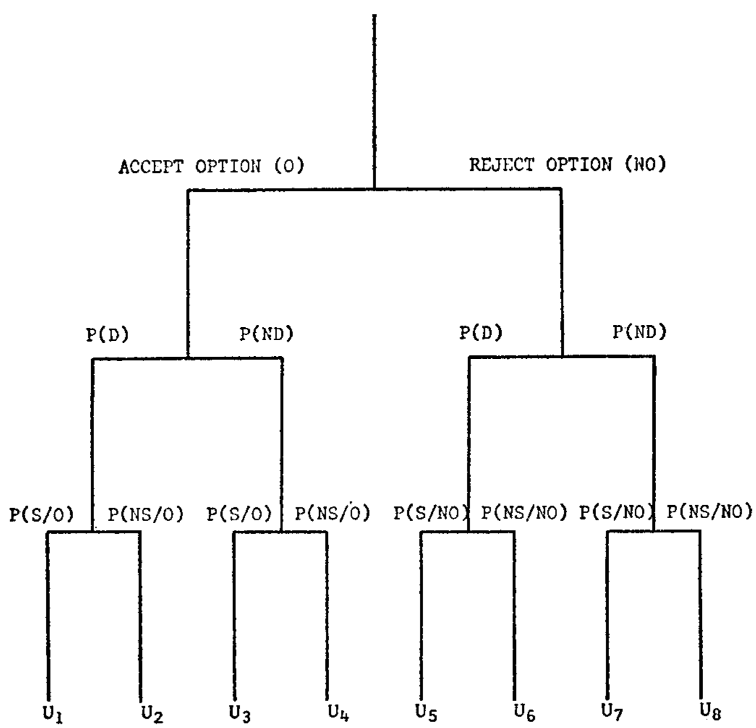

FIGURE 1

Von Neumann-Morgenstern game tree showing the eight possible outcomes from the choice to accept or reject an option.

$$U_{no} = P(D)[U_5 . P(S/NO) + U_6 . P(NS/NO)] + P(ND)[U_7 . P(S/NO) + U_8 . P(NS/NO)] \qquad (2)$$

By definition, the maximum option price is that price which makes:

$$U_o = U_{no}$$

Option value will be considered under two sets of conditions:

1. Demand is uncertain.
2. Supply is uncertain.

Uncertain Demand

(a) *Price compensating approach*

In this case, let:

$$P(D) = p \quad \text{where } 0 < p < 1$$

A simplifying assumption is made that the supply of the good to be valued is certain and that supply exclusion can be enforced. Using the price compensating approach:

$$\begin{aligned} P(S/O) &= 1 \\ P(S/NO) &= 0 \\ P(NS/O) &= 0 \\ P(NS/NO) &= 1 \end{aligned}$$

Substituting these values into Equation 1 and Equation 2 gives:

From Equation 1 $\quad U_o = pU_1 + (1 - p)\, U_3$

From Equation 2 $\quad U_{no} = pU_6 + (1 - p) U_8$

From Figure 2 it can be seen that the indifference curve mapping of utilities from the 'demand' choice (i.e. U_1, U_2, U_5, U_6) do not correspond to the indifference curve mapping of utilities from the 'no demand' choice (i.e. U_3, U_4, U_7, U_8). The two mappings overlap. Because future demand is a probabilistic event, either the 'demand' case or the 'no demand' case will occur. For an individual, both cases cannot occur at once. Consequently, to find the maximum option price, OPc, using the $U_o = U_{no}$ criterion, the utilities on both sides of the equation must come from the same mapping. This can be achieved by assuming that the price charged for the good (as specified in the option) turns out to be the maximum discriminating price. Therefore, an individual who accepted an option and became eligible to purchase the good involved, would be indifferent between demanding (and paying for) the good, and not demanding it.

Using this assumption:

$$\begin{aligned} U_1 &= U_3 \\ U_5 &= U_8 \end{aligned}$$

So:

$$\begin{aligned} U_o &= U_1 \\ U_{no} &= U_5 - p(U_5 - U_6) \end{aligned}$$

The maximum option price makes $U_o = U_{no}$

i.e. $\quad U_1 = U_5 - p(U_5 - U_6)$.

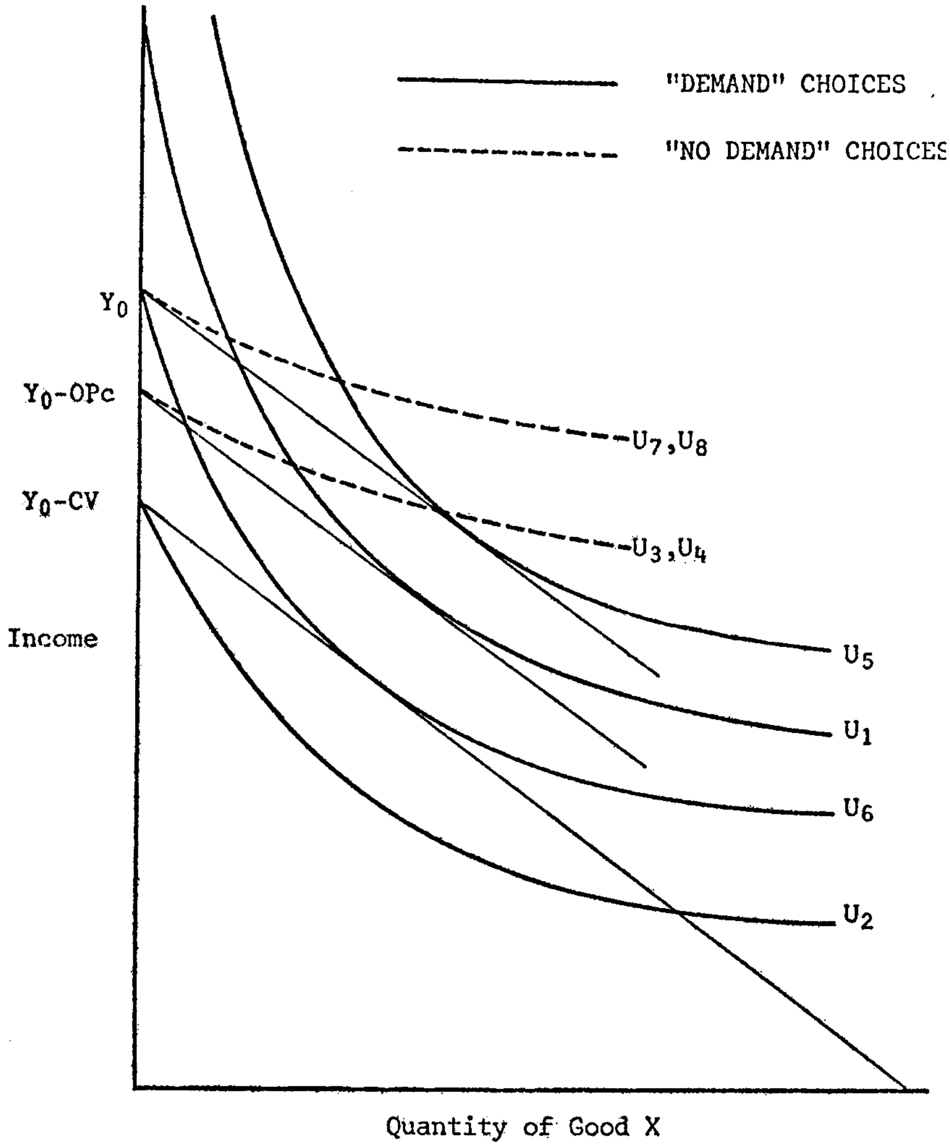

FIGURE 2

Indifference curves associated with the choice between demanding and not demanding good X. Price compensating approach.

Referring to Figure 2, the maximum price is OPc such that U_1 is somewhere between U_5 and U_6, depending on the size of p.

As p tends to zero, OPc tends to zero.

As p tends to one, OPc tends to CV.

Having found the maximum option price in theoretical terms, it is now possible to find the conditions for which it differs from the expected consumer's surplus, so that option value exists.

The relationship between OPc and expected consumer's surplus (exp CS) can be shown by a Friedman-Savage type of diagram, which relates utility and income. Figure 3 shows the relationship between utility and

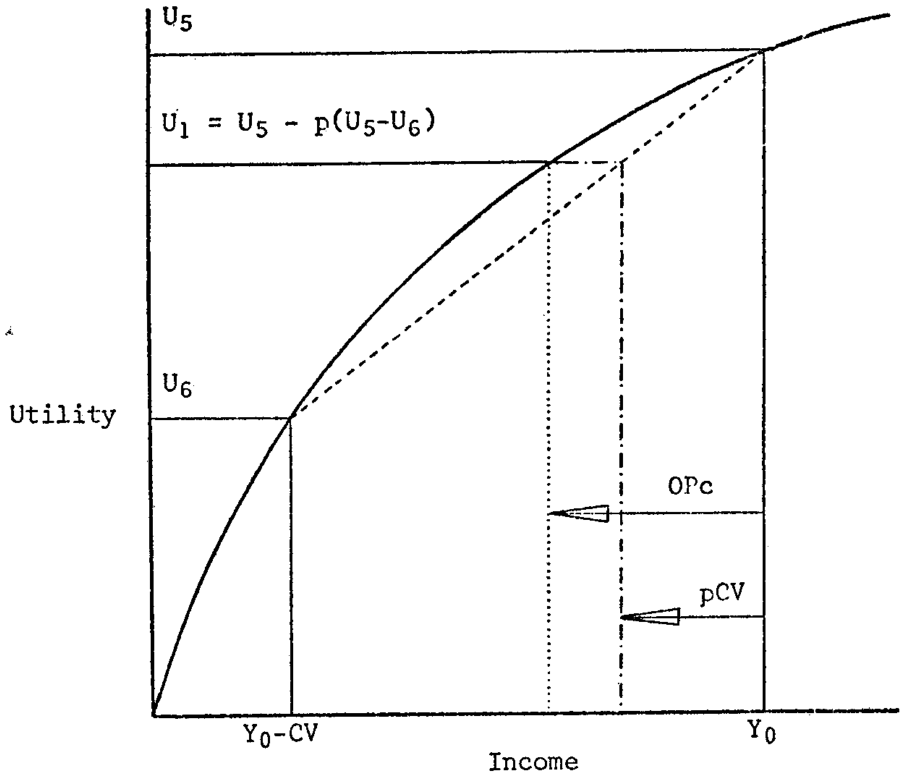

FIGURE 3

Friedman-Savage curve for a risk averse person

$U = f(Y)$ such that:
(i) $dU/dY > 0$
(ii) $d^2U/dY^2 < 0$

It is assumed that there is no consumption of X. Therefore, all utilities are related to their money values (through the 'no demand' indifference mapping), so that they are comparable.

income for an individual with a risk averse preference structure. Risk aversion is expressed by the individual's declining marginal utility of income.

The risk averse person described by Figure 3 is prepared to pay an option price of OPc to ensure the availability of good X in the future, although the consumer's surplus that he expects to derive is only pCV. Since OPc is greater than pCV in this example, positive option value exists.

People with constant marginal utilities of income would have zero option value because OPc would equal pCV, and gamblers, with increasing marginal utilities of income, would have negative option values because OPc would be less than pCV. So, the personality of each person influences the size and sign of the option value placed on a good by him.

(b) *Price equivalent approach*

In a similar way, it can be shown that option value exists in the price equivalent case. The maximum option price that a consumer demands, to compensate for the removal of the opportunity to purchase a good in the future, may differ from the expected consumer's surplus from future purchases. As in the price compensating case, option value is positive for risk averters, negative for gamblers and zero for consumers with a constant marginal utility of money.

For risk averters, OVe is more positive than OVc, and for gamblers, OVe is less negative than OVc. Therefore, OVe is greater than OVc for individuals in both of these categories. The only exception is for individuals with a constant marginal utility of money, for whom OVe and OVc are both equal to zero.

Uncertain Supply

Supply is uncertain if $P(S/O) < 1$ in the price compensating case, or if $P(S/NO) < 1$ in the price equivalent case.

In general, the absolute value of option value is reduced as conditions surrounding supply become more uncertain.

For a good which is being introduced, the price compensating approach can be used to show that risk averters with uncertain future demand will place a positive option value on the good if buying the option increases the probability of future supply being available, i.e. if $P(S/O) > P(S/NO)$. Conversely, for a good which is being withdrawn, the relevant condition for risk averters to have positive option values under the price equivalent approach, is $P(S/O) < P(S/NO)$.

Discussion of Option Values

The size of the option value of a good is directly related to the following conditions:

1. The degree of risk aversion among potential consumers.
2. The degree of demand uncertainty among potential consumers.
3. The degree of supply certainty, as expressed by the effectiveness of exclusion.
4. The difficulty involved in restoring the supply of the good once it has been curtailed or abandoned.
5. The lack of suitable substitutes for the good.
6. The non-storability of the good.
7. The number of potential consumers.

The relationship between option value and the probability of future demand is given in Figure 4. The values for option price and consumer's surplus were found by testing a range of probabilities of demand on the Friedman-Savage curve of Figure 3. From Figure 4 it can be seen that option value is most important when the probability of demand is low. When a good is subject to a low probability of demand from a large number of risk averse potential consumers, option value is a large proportion of the total value of the good.

Krutilla *et al.* (1972) claimed that option value for a good can also exist when future demand is certain, if the future consumers are dispersion averse. For example, using the price compensating approach, consumers who are certain of their future demand may be prepared to pay a maximum option price which is greater than their expected consumer's surplus, if the variance of the expected outcome from the 'option' case is less than the variance of the expected outcome from the 'no option' case. In this example, the option value would be a

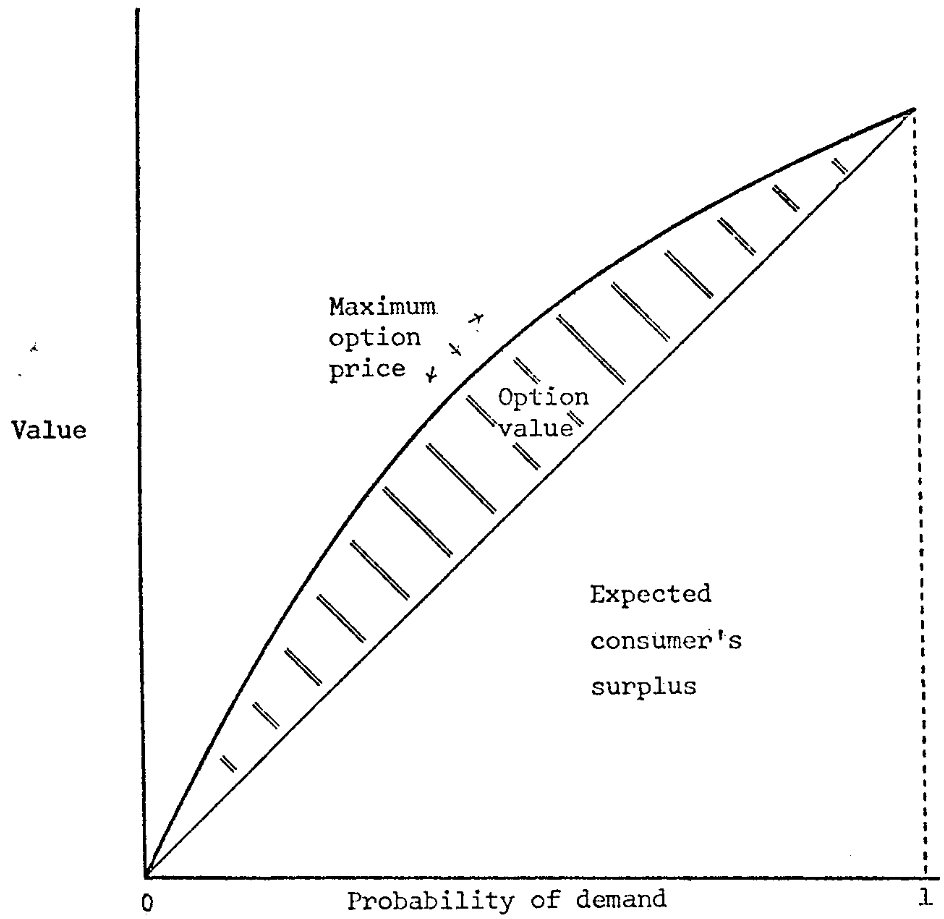

FIGURE 4

Relationship between option price, option value, expected consumer's surplus, and the probability that a risk averse potential user becomes an actual user.

premium against dispersion. When demand is uncertain, and the variances of the expected outcomes differ, then the composite option value contains a premium against dispersion as well as a premium against risk.

The profitability of insurance companies shows that positive option values exist in the real world. People are prepared to pay a surcharge (i.e. option value) above the fair price (i.e. expected money pay-off) in order to ensure compensation for the effects of randomly occurring misfortunes.

Option values of important size have been shown to exist under a specified range of conditions. Some issues involved in the application of option value theory to the real world will be considered.

How to Use Option Values

As a first step, the option values of all goods which will be produced or eliminated as a result of a resource allocation decision could be considered. Despite its origin as a defence for natural assets, other goods may also have option values.

Suppose that it has been proposed that a dam be built in a particular valley, and a decision must be made whether to build the dam or leave the valley in its natural state. Conservationists are typically quick to find reasons for not building the dam, and often unwittingly invoke the principle of option value to support their case. An economist charged with the task of constructing a decision model for this problem would try to evaluate the two alternatives. If option values are to be considered, then they need to be found for the goods involved in both alternatives.

The fate of the Murray River valley in the south-west of Western Australia provides an example of this type of decision problem. To overcome the projected inadequacy of Perth city's present sources of water, it has been proposed that a dam be built in the Murray Valley.

If both the conservation and dam alternatives are to be evaluated in money terms, the total value of every item in each alternative needs to be found. The total value of each item would include the sum of its expected user receipts, expected consumer's surpluses and option values.

Considering the Murray Valley example in more detail, there are a number of items in each alternative which could have large option values. Some examples are given below.

(a) *Option values of goods associated with the valley in its natural state*

1. Option values associated with valley activities such as picnicking, bushwalking, camping, canoeing, cascading, rock climbing, marron fishing and nature study.

2. Option values of estuary-based activities which could be threatened by the building of a dam on the Murray River. The Peel Inlet is an almost landlocked estuary covering 25 square miles. Of the major streams which flow into Peel Inlet, only the Murray River has not been dammed. Therefore, damming the Murray River could have severe effects on water-based activities in Peel Inlet, such as fishing and crabbing.

(b) *Option values of goods associated with a dam in the Murray Valley*

1. Option values of the activities which could take place in the catchment area. At present, human activity in domestic water supply catchments in Western Australia is strongly discouraged, but this attitude may change in the future. Some domestic water storages in Europe are used extensively for recreation activities such as fishing, camping and boating.

2. Option value of the availability of an adequate supply of water. The option value of future water supplies may be very high for a community with a high risk aversion to drought.

When to Use Option Values

Option values are important when conditions are such that the option value of a good is likely to be a sizeable portion of its total value. However, option values need not be quantified unless a resource allocation decision is likely to be altered by their inclusion. Two conditions under which option values could be irrelevant are:

1. The value (net of option value) of one alternative exceeds that

of the other alternative by more than the difference between their option values.

2. Both alternatives have similar option values, so that option values could be ignored without biasing the decision.

In both of the above cases, the decision whether or not to quantify the option value of a good could be made on the basis of an intuitive estimate of its option value. Such estimation would involve consideration of the nature of the good, and the conditions governing its supply and demand. In practice, considerable experience with quantifying and handling option values would be needed before the importance of the option value of a particular good could be estimated in this way.

Quantifying Option Values

No simple and reliable method exists for the measurement or calculation of option value.

One approach which has been suggested (Krutilla *et al.*, 1972) would involve close analysis of the behaviour and attitudes of a sample of individuals. To find the option value that a consumer places on a particular good, it would be necessary to find his preference structure, his subjective probability of demanding the good in the future, the value that he places on being able to use the good, and the compensation that he would require if the good were not available. The total option value of the good could then be found by summing the individual option values placed on it by its potential consumers.

This approach to the use of option value is to calculate it separately, and then add it to consumer's surplus and user receipts to give the total value of a good. However, since the measurement of consumer's surplus is usually difficult, and the techniques for estimating option value are ill-defined, it may prove more useful to concentrate on the development of reliable methods to estimate maximum option price, since the combined consumer's surplus and option value of a good would be given in one step. The replacement of consumer's surplus by the more versatile concept of maximum option price may be simpler than the adjustment of consumer's surplus by adding option value.

Instead of using the direct questioning of a small sample of potential consumers in order to collect enough information to enable the option value of a good to be estimated, it may be possible to estimate option prices from observed aspects of the collective behaviour of a community.

For example, it may be possible to specify a general function to describe option value in terms of a few independent variables. Some of the appropriate variables may relate to the nature of the community. Others may relate to the nature of the good and the availability of substitutes. If a general option value function could be found, then the estimation of the option value of a particular good would be a relatively simple task.

References

Gallagher, D. R. Option value, the social discount rate and the environment. Paper presented at ANZAAS 45th Congress, Perth, Western Australia. August 1973.

Hicks, J. R. The four consumer's surpluses. *Review of Economic Studies* 11: 31-41. 1944.

Krutilla, J. V., Cicchetti, C. J., Freeman III, A. M. and Russel, C. S. Observations on the economics of irreplaceable assets. In Kneese, A. V. and Bower, B. T. (Eds) *Environmental Quality Analysis: Theory and Method in the Social Sciences.* John Hopkins Press, Baltimore. 1972.

Lindsay, C. M. Option demand and consumer's surplus. *Quarterly Journal of Economics* 83: 344-6. 1969.

Long, M. F. Collective consumption services of individual-consumption goods: Comment. *Quarterly Journal of Economics* 81: 351-352, 1967.

Schmalensee, R. Option demand and consumer's surplus valuing price changes under uncertainty. *American Economic Review* 62: 813-824. 1972.

Weisbrod, B. A. Collective-consumption services of individual consumption goods. *Quarterly Journal of Economics* 78: 471-477. 1964.

Zeckhauser, R. Resource allocation with probabilistic individual preferences. *American Economic Review. Proceedings and papers* 59: 546-552. 1969.