INFROMATION, OPTION, AND EXISTENCE VALUE[+]

by

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June 1979 79-15

+Presented at the American Agricultural Economics Association meetings, Pullman, Washington, July 30 - August 1, 1979

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Abstract

An intergenerational model of resource development is constructed to examine the concepts of option and existence value. These concepts are seen to relate to a more fundamental concept: the expected value of perfect information. The analysis would suggest that when sequencing irreversible resource developments both uncertainty and the expected value of information should be considered.

I. Introduction

Since its introduction by Weisbrod (1964), the concept of option demand has stimulated extensive discussion by economists interested in the problem of evaluating commodities with public good attributes. As initially posed, option demand could arise when considering a decision to curtail the supply of a commodity whose future demand by individuals is uncertain and where expansion or reestablishment of the commodity is technically impossible or excessive in cost. In such a situation, prospective consumers of the commodity might be willing to pay some lump sum in order to preserve the option of future demand.

Subsequent to Weisbrod's seminal work, analysis focused on the relationship between option value and expected consumer surplus (Long 1967, Lindsay 1969 and Byerlee 1971). Cicchetti and Freeman (1971) showed that when individuals are risk averse, a perfectly discriminating monopolist selling options to purchase the good in the future at some specified price, will obtain revenues whose present value exceeds expected consumers surplus. Option value becomes a risk premium.

Stimulated in part from an article by Arrow and Lind (1970), which examined the effects of risk spreading in public investments, Arrow and Fisher (1974) identified a "quasi-option value" which derived from a Bayesian information structure in conjunction with development irreversibility. This quasi-option value obtained even when evaluating a projects net benefits at their expected value, as would be appropriate when no individual had a significant stake in its costs or benefits, (ie., the projects impact was spread thinly among many individuals).

Finally, a third benefit flow - existence value - would seem distinct (at least conceptually) from either option or quasi-option value. Existence value would derive from known nondemanders who wish to preserve an irreplaceable natural environment out of deference to succeeding generations whose demand (value) for such environs is uncertain. As noted by Krutilla and Fisher (1975), existence value would arise out of a bequest motive by the current generation.

The purpose of this paper is to identify option and existence values within a single model and relate them to their common source: the expected value of perfect information. Space precludes a discussion of the quasi-option value. A more detailed discussion of all three concepts may be found in Conrad (1979).

II. A model of Intergenerational Resource Allocation Under Uncertainty

For simplicity of exposition we will relate the various concepts within a simple two period model where:

M_o = The state of material (man-made) wealth inherited by the current generation

N_o = The state of the natural environment inherited by the current generation

D_o = The level of development activity by the current generation

M_1 = $(1-\alpha)\, M_o + G(D_o)$ = The state of material wealth actually enjoyed by the current generation and bequeathed to the next (future) generation. Note: the stock of material wealth will diminish at rate α unless development takes place which will augment the stock of material wealth according to the concave function $G(D_o)$.

$N_{1,s}$ = $N_o - F_s(D_o)$ = The state of the natural environment actually enjoyed by the current generation in state s and bequeathed to the next generation where $F_s(D_o)$ is a convex degradation function specifying the diminishment in natural amenities in state s associated with the level of development D_o.

p_s = The subjective probability for the occurrence of state s held by the current generation, where $0 < p_s < 1$ and

$$\sum_s p_s = 1$$

W_s = $W(M_1, N_{1,s}) + \delta T(M_1, N_{1,s})$ = The welfare of the current generation in state s as determined by the direct utility derived by that generation from M_1 and $N_{1,s}$ as well as the utility derived from leaving the next generation a particular endowment. Thus, $T(\cdot)$ represents the current generation's perception of what alternative endowments are worth to the next generation, and δ is the weight (significance) attached to that perception.

The above model might be thought of as representing the last two periods of a multiperiod control problem where the activity of all preceeding generations is captured by the initial conditions M_o and N_o and the problem of the current generation is to select the level of irreversible development based on their preferences for material wealth and natural amenities as well as a concern for the choices left open to the next (last) generation (in part determined by their endowment M_1 and $N_{1,s}$).

Suppose the criterion adopted by the current generation was the maximization of expected welfare. This might be expressed mathematically as

$$\underset{D_o}{\text{Max}}: \quad W = \sum_s p_s \left\{ W(M_1, N_{1,s}) + \delta T(M_1, N_{1,s}) \right\}$$

Subject to: $M_1 = (1-\alpha)\, M_o + G(D_o)$

$$N_{1,s} = N_o - F_s(D_o)$$

$$D_o \geq 0$$

Substituting the equations for M_1 and $N_{1,s}$ directly into the expression for expected welfare and differentiating with respect to D_o yields the following Kuhn-Tucker condition:

$$(1) \quad \sum_s p_s \left\{ \left(\frac{\partial W}{\partial M_1} + \delta \frac{\partial T}{\partial M_1}\right) \frac{dG_o}{dD_o} - \left(\frac{\partial W}{\partial N_{1,s}} + \delta \frac{\partial T}{\partial N_{1,s}}\right) \frac{dF_s}{dD_o} \right\} D_o = 0$$

Equation (1) is a decision rule for the level of development and has the following two part interpretation:

(a) If the initial stocks of M_o and N_o are such that the expected marginal welfare from development exceeds the expected marginal welfare loss in natural amenities, development will occur ($D_o > 0$) until they are equal,

(b) If the initial stocks of M_o and N_o are such that the expected marginal welfare from development equals or is less than the expected marginal welfare loss in natural amenities, no development will occur ($D_o = 0$)

The decision rule as it presently stands contains the possibility of both option and existence values. We may quickly isolate these values by a series of special cases.

III. Pure Option Value ($\delta = 0$)

Suppose the current generation attached no weight to the value of the next generation's endowment and simply sought a development policy which would maximize its expected welfare. Such would be the case if δ were set equal to zero. The decision rule for determining D_o becomes

$$(2) \quad \sum_s p_s \left\{ \frac{\partial W}{\partial M_1} \frac{dG}{dD_o} - \frac{\partial W}{\partial N_{1,s}} \frac{dF_s}{dD_o} \right\} D_o = 0$$

The same two part interpretation given to equation (1) may be applied to equation (2) only now the expected marginal welfare and amenity loss pertain strictly to the direct benefits enjoyed and foregone by the current generation as evaluated by $W(\cdot)$. Option value will exist when $W(\cdot)$ is concave in $N_{1,s}$; in that the welfare consequences of a development decision are not known with certainty. A numerical example at this point might help to clarify the issues facing this egocentric, risk averse collection of individuals.

Table I presents a numerical example specifying initial conditions for material wealth and the natural environment, transition equations, and a welfare function ordering alternative combinations of M_1 and $N_{1,s}$. The transition equation for material wealth encorporates a 5% rate of depreciation on the current stock of wealth and a concave production function relating development to M_1. The transition equation for the natural environment involves a stochastic process which specifies two degradation functions, one for each of the two equally likely states, (ie, s=1,2 and $p_1 = p_2 = 0.50$).

Suppose the current generation were restricted to four development alternatives D_o = 0,1,4 and 9. The body of Table I contains the values for M_1, $N_{1,s}$

Table I

A Numerical Example of Intergenerational Resource Allocation

$M_o = 5.00,\quad N_o = 10.00,\quad p_1 = p_2 = 0.50,\quad a = 0.05$

$M_1 = (1-a)M_o + G(D_o) = 4.75 + 0.50\,D_o^{0.75}$

$$N_{1,s} = N_o - F_s(D_o) = 10.00 - \begin{cases} 0.50\,D_o^{0.25} & \text{when } s=1 \\ 3.00\,D_o^{0.50} & \text{when } s=2 \end{cases}$$

$W_s = W_{1,s}(\cdot) + \delta T_{1,s}(\cdot) = M_1\,N_{1,s}^{0.50} + \delta M_1^{0.75}\,N_{1,s}^{0.75}$

D_o	0	1	4	9
M_1	4.75	5.25	6.16	7.35
$N_{1,1}$	10.00	9.50	9.29	9.13
$N_{1,2}$	10.00	7.00	4.00	1.00
$W_{1,1}$	15.02	16.18	18.78	22.21
$W_{1,2}$	15.02	13.89	12.32	7.35
$T_{1,1}$	18.09	18.77	20.81	23.44
$T_{1,2}$	18.09	14.93	11.06	4.46
W_1 $(\delta=0)$	15.02	16.18	18.78	22.21
W_2 $(\delta=0)$	15.02	13.89	12.32	7.35
W $(\delta=0)$	15.02	15.04	15.55	14.78
W_1 $(\delta=1)$	33.11	34.95	39.59	45.65
W_2 $(\delta=1)$	33.11	28.82	23.38	11.81
W $(\delta=1)$	33.11	31.89	31.49	28.73

and $W_{1,s}$ which result given the initial conditions, functional forms, and alternative values of D_o. Note, that with no development (D_o=0) there is no uncertainty: material wealth declines to 4.75 and $N_o = N_{1,s} = 10.00$ for s = 1,2. With a positive level of development the stochastic process on $N_{1,s}$ inturn induces two alternative welfare states evaluated as $W_{1,1}$ and $W_{1,2}$. With no bequest motive (δ=0) we can ignore the values calculated for $T(\cdot)$, note that $W_s = W_{1,s}$ and calculate the expected welfare for each development alternative. The maximum expected welfare is W = 15.55 achieved when $D_o = 4$.

What would be the value to the current generation if it could delay its development decision until the precise state of nature were known with certainty? Moving across the rows W_1 and W_2 for $\delta = 0$ one can see that such an option would be valuable indeed. If it were known that state one was to occur the current generation would chose $D_o = 9$ yielding $M_1 = 7.35$ and only a slight reduction in natural amenities to $N_{1,1} = 9.13$ for a welfare index of 22.21. Alternatively if it were known that state two was to occur they would choose $D_o = 0$ yielding $M_1 = 4.75$, $N_{1,2} = 10.00$ and a welfare index W = 15.02. The value of the option to delay the development decision is equivalent to what decision theorists refer to as the expected value of perfect information (Raiffa 1968, p. 28) and is readily calculated in Table II.

The expected value of perfect information can be explained a number of ways. It is defined as the minimum of the expected opportunity loss (EOL). Table II contains the opportunity loss associated with each of the development alternatives when compared to the maximum welfare value which could be achieved in each state. Thus in state one the preferred development decision is $D_o = 9$. If $D_o = 0$ had been chosen an opportunity loss of 22.21 - 15.02 = 7.19 would have resulted. We may compute the opportunity loss for each level of D_o in

Table II
Pure Option Value ($\delta=0$)

D_o	0	1	4	9
Opportunity loss (s=1)	7.19	6.03	3.43	0.00
Opportunity loss (s=2)	0.00	1.13	2.70	7.67
Expected opportunity loss	3.60	3.58	3.07	3.84

Table III
Option and Existence Value ($\delta=1$)

D_o	0	1	4	9
Opportunity loss (s=1)	12.54	10.70	6.06	0.00
Opportunity loss (s=2)	0.00	4.29	9.73	21.30
Expected opportunity loss	6.27	7.50	7.90	10.65

Table IV
Intergenerational Resource Allocation When $W_s = M_1 + \delta M_1^{0.75} N_{1,s}^{0.75}$ ($\delta=1$)

D_o	0	1	4	9
M_1	4.75	5.25	6.16	7.35
$N_{1,1}$	10.00	9.50	9.29	9.13
$N_{1,2}$	10.00	7.00	4.00	1.00
$W_{1,1}$	4.75	5.25	6.16	7.35
$W_{1,2}$	4.75	5.25	6.16	7.35
$T_{1,1}$	18.09	18.77	20.81	23.44
$T_{1,2}$	18.09	14.93	11.06	4.46
W_1 ($\delta=1$)	22.84	24.02	26.97	30.79
W_2 ($\delta=1$)	22.84	20.18	17.22	11.81
W ($\delta=1$)	22.84	22.10	22.10	21.30

Table V
Pure Existence Value When $W_s = M_1 + \delta M_1^{0.75} N_{1,s}^{0.75}$ ($\delta=1$)

D_o	0	1	4	9
Opportunity loss (s=1)	7.95	6.77	3.82	0.00
Opportunity loss (s=2)	0.00	2.66	5.62	11.03
Expected opportunity loss	3.98	4.72	4.72	5.52

each state in a similar fashion. Weighting each loss by the subjective probabilities and adding we can calculate the EOL. The minimum in this case is 3.07 again at $D_o = 4$.

Alternatively, the value of an option to delay development until ascertaining the true state might be calculated by subtracting the value of expected welfare with no information from the value of expected welfare with perfect information. Recall, if state one were to occur $D_o = 9$ would be chosen. If state two were to occur $D_o = 0$ would be chosen. Assuming the probability of each state occurring remains at 0.5 (ie., this stochastic feature is not altered by perfect information), then the expected welfare with perfect information is $W^* = 0.5(22.21) + 0.5(15.02) = 18.62$. From Table I we noted that the maximum expected welfare without any information occured at $D_o = 4$ where $W = 15.55$. The difference $W^* - W = 3.07$ is the same as the minimum of the EOL.

IV. Option and Existence Value ($\delta > 0$)

With a bequest motive some weight is attached to the endowment left for the next generation. Since the states of material wealth and natural amenities enjoyed by the current generation are simultaneously the endowment left the next generation the development decision adopted, (according to equation (1)), will in general be influenced by $\delta T(\cdot)$, and thus different from the development decision taken by the egocentrics when $\delta = 0$.

Suppose, as is the case in Table I, that $\delta = 1$, and that current generation's welfare in state s is defined by $W_s = M_1 N_{1,s}^{0.50} + M_1^{0.75} N_{1,s}^{0.75}$. As before, a positive level of development will initiate a stochastic process affecting the level of natural amenities, and welfare. Both direct and indirect (bequest) components will vary from state to state. The effect of alternative development levels on the value of the next generations' endowment are shown in rows $T_{1,1}$ and $T_{1,2}$. With $\delta = 1$ direct and bequest evaluations are added and presented in rows $W_s(\delta=1)$.

Expected welfare is calculated in the usual fashion and given in the last row as $W(\delta=1)$.

The maximum expected welfare now results when $D_o = 0$. In terms of equation (1) we have a corner solution described in interpretation (b). Both option and existence values are present. The value of an option permitting the current generation to delay the development decision until the true state is known is again equivalent to the expected value of perfect information and is computed in Table III as the minimum of the EOL equal to 6.27 at $D_o = 0$.

V. Pure Existence Value

Suppose now that the current generation derived no utility from natural amenities but they perceived that the next generation would and are influenced by that perception. Such a situation would arise if the welfare of the current generation could be expressed as $W_s = M_1 + \delta M_1^{0.75} N_{1,s}^{0.75}$ as shown in the heading to Table IV. Note that the direct utility enjoyed by the current generation is deterministic and in this case equal to the level of material wealth. Overall welfare is stochastic, however, induced by the stochastic endowment term.

What sort of development policy would be adopted by this materialistic but alturistic generation? Table IV contains the values for material wealth, the state of the natural environment and welfare in this case. The values for M_1 and $N_{1,s}$ are identical to those in Table I under the presumption that the initial conditions, transition equations, and development alternatives are as before. With $\delta = 1$ the evaluation of alternative endowments, found in rows $T_{1,1}$ and $T_{1,2}$ are also identical to those in Table I. The difference between Tables I and IV, arising out of the altered welfare function, occur in the rows for direct, total and expected welfare. The development policy yielding the highest expected welfare is again $D_o = 0$ resulting in $M_1 = 4.75$, $N_o = N_{1,s} = 10.00$ and an expected welfare of $W = 22.84$. With no bequest motive the current generation would have adopted a development policy of $D_o = 9$ resulting in $M_1 = W = 7.35$. Existence value, equivalent to the expected value of perfect information is calculated in Table V where the minimum of the EOL is 3.98 at $D_o = 0$.

VI. Conclusions and Policy Implications

The central conclusion of this paper is that the concepts of option and existence value all derive from a more fundamental concept: the expected value of perfect information. In the preceeding intergenerational model as well as within the individualistic models in which option value was initially discussed, the value of delay is equivalent to the expected value of perfect information. This equivalency arose when a generation (or individual) could learn precisely (or predict) the true state of environmental degradation. A more realistic situation is one where succeeding generations can learn from the experiences of the current generation but that information is less than perfect. In such a case quasi-option value, equal to the expected value of (imperfect) information will arise. Learning may be passive (see Conrad 1979) or active (see Rausser 1978).

When considering irreversible resource developments, (perhaps the sequencing of energy developments which might cause irreversible environmental damage), the following additions to traditional project analysis would seem appropriate:

(a) The current state of knowledge must be examined to determine the extent of our ignorance about the costs of irreversible actions and

(b) The expected value of delay should be assessed in terms of the value that future information might have in determining the appropriate level of irreversible development

In summary, the value of an option, be it for ourselves or future generations, derives in part from what we can expect to learn. It seems only reasonable that agencies evaluating natural resource developments explicitly incorporate such values to sequence irreversible investments.

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