Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

Working Paper No. 374

QUASI-OPTION VALUE: SOME MISCONCEPTIONS DISPELLED

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July 1985

Quasi-Option Value: Some Misconceptions Dispelled

In this note we discuss some issues raised in the recent article by Freeman [4] on quasi-option value. Arrow and Fisher (AF) [1] originally introduced the concept in the context of an irreversible development decision where information about the future consequences of development would arrive with time independently of the development decision itself. We shall refer to this scenario as "independent learning." Within this framework, AF showed that there is a positive quasi-option value of preservation and argued that, when the possibility of acquiring this information is recognized, there is a stronger case for postponing irreversible development actions than when no such possibility exists. In the first part of his paper, Freeman reviews this issue and appears to disagree with both of these conclusions. We show below that the AF conclusions are correct and that the source of Freeman's difference is a confusion between quasi-option value, which is always positive, and the net benefit of preservation which is not. In the second part of his paper, Freeman considers a different scenario where the relevant information can be obtained only by undertaking some development and shows that this changes AF's conclusions. The same point was made independently by Miller and Lad [6]. We refer to this scenario as "dependent learning." We shall offer some comments on the significance of this scenario and expose the similarities, as well as the differences, with the independent learning scenario.

INDEPENDENT LEARNING

In Freeman's model, which is patterned after that of AF, there are two periods; and the decision concerns the proportion of some resource to be developed in each period. Let d_t be the proportion developed in period t = 1, 2 where $d_1 \leq 1$, $d_1 + d_2 \leq 1$. The development is irreversible, so that $d_t \geq 0$, t = 1, 2. The net benefit function in period 1 is known with certainty to be $B_1(d_1) = d_1 B_1$ for some constant $B_1 \gtrless 0$. By contrast, the net benefits in period 2 are uncertain, being given by

$$B_2(d_1, d_2) = \begin{cases} (d_1 + d_2)\beta & \text{with probability } p \\ (d_1 + d_2)\alpha & \text{with probability } (1 - p) \end{cases}$$

where $\beta > 0$ and $\alpha < 0$. Proceeding slightly differently from Freeman, we shall focus attention on the first-period decision--i.e., the choice of d_1. We assume that, however d_1 is chosen, d_2 is chosen optimally in the light of this decision. Following Freeman and AF, we distinguish between two information scenarios. In the first scenario, the uncertainty about the second period consequences of development will <u>not</u> be resolved before d_2 must be chosen. Therefore, using the notation introduced by Hanemann [5], the expected net benefits over both periods as a function of d_1 are given by

$$V^*(d_1) \equiv d_1 B_1 + \max_{\substack{d_2 \\ 0 \leq d_2, d_1 + d_2 \leq 1}} E\{B_2(d_1, d_2)\}$$

and the correct decision in the first period is d_1^* where

$$d_1^* = \arg \max_{0 \leq d_1 \leq 1} V^*(d_1).$$

In the second scenario the uncertainty <u>will</u> be resolved by the beginning of period 2 so that it makes sense to defer a decision on d_2 in order to exploit this information. In that case, the expected net benefits as a function of d_1 are

$$\hat{V}(d_1) \equiv d_1 B_1 + E\{ \max_{\substack{d_2 \\ 0 \le d_2, d_1 + d_2 \le 1}} B_2(d_1, d_2)\}$$

and the correct decision in the first period is $\hat{d}_1$ where

$$\hat{d}_1 = \arg \max_{0 \le d_1 \le 1} \hat{V}(d_1).$$

A distinctive feature of Freeman's model, as well as the AF model, is the linearity of the net benefit functions in d_1 and d_2. This implies that there is a corner solution with $d_t = 0$ or 1 for both $t = 1$ and $t = 2$. Therefore, we concern ourselves only with $\hat{V}(0)$, $\hat{V}(1)$, $V^*(0)$, and $V^*(1)$. We observe that

$$\hat{V}(0) = p\beta \tag{1}$$

$$\hat{V}(1) = V^*(1) = B_1 + p\beta + (1 - p)\alpha \tag{2}$$

and

$$V^*(0) = \begin{cases} p\beta + (1 - p)\alpha & \text{if } p\beta + (1 - p)\alpha > 0 \\ 0 & \text{otherwise.} \end{cases} \tag{3}$$

Freeman, in fact, assumes that $p\beta + (1 - p)\alpha > 0$, but this is not essential to the argument. Turning to the first-period decision, it is evident that the correct choice in the first scenario is

$$d_1^* = \begin{cases} 0 & \text{if } V^*(0) > V^*(1) \\ 1 & \text{otherwise} \end{cases} \tag{4}$$

while the correct choice in the second is

$$\hat{d}_1 = \begin{cases} 0 & \text{if } \hat{V}(0) > \hat{V}(1) \\ 1 & \text{otherwise.} \end{cases} \tag{5}$$

AF introduce their concept of quasi-option value in the following manner. Suppose that, in contemplating whether to permit development, a decision-maker behaves according to (4) ignoring the possibility of further information and setting d_1 and d_2 on the basis of his current expectation of the future consequences of development. If it is, in fact, possible to wait and determine d_2 after the uncertainty is resolved, this is suboptimal. The inefficiency can be corrected by introducing a shadow tax on development--i.e., the quasi-option value, V_q-- so that instead of comparing V*(0) with V*(1) in (4) the decision-maker will compare V*(0) with $[V^*(1) - V_q]$. In order to elicit the correct decision, the quasi-option value must satisfy the condition

$$V^*(0) - [V^*(1) - V_q] = \hat{V}(0) - \hat{V}(1). \tag{6}$$

From (2) it follows that

$$V_q = [\hat{V}(0) - \hat{V}(1)] - [V^*(0) - V^*(1)] = \hat{V}(0) - V^*(0). \tag{7}$$

Moreover, it can be seen from (4) and (5) that

$$V_q \geq 0 \Rightarrow \hat{d}_1 \leq d_1^* \tag{8}$$

Now we can calculate the net benefit of preservation over development and the optimal decision rule in Freeman's example. From (1) and (2)

$$\hat{V}(0) - \hat{V}(1) = -B_1 - (1 - p)\,\alpha \tag{9}$$

$$\hat{d}_1 = \begin{cases} 0 & \text{if } B_1 + (1 - p)\,\alpha < 0 \\ 1 & \text{otherwise.} \end{cases} \tag{10}$$

From (1), (3), and (7) the quasi-option value is

$$V_q = \begin{cases} -(1 - p)\,\alpha > 0 & \text{if } p\beta + (1 - p)\,\alpha > 0 \\ p\beta > 0 & \text{otherwise.} \end{cases} \tag{11}$$

It follows that V_q is unambiguously positive contrary to Freeman's assertion. His error arises from a confusion between AF quasi-option value, V_q, and the expression for $[\hat{V}(0) - \hat{V}(1)]$ which he mistakenly identifies with V_q at the foot of page 293. (In his notation, $E_3 = \hat{V}(0)$ and $E_1 = V^*(1)$ which from (2) is just equal to $\hat{V}(1)$; and he defines V_q as $E_3 - E_1$.) Observe also that

$$V^*(0) - V^*(1) = \begin{cases} -B_1 & \text{if } p\beta + (1 - p)\,\alpha > 0 \\ -B_1 - p\beta - (1 - p)\,\alpha & \text{otherwise.} \end{cases} \tag{12}$$

Comparing (9) and (12), we conclude that, regardless of whether $p\beta + (1 - p)\,\alpha \gtrless 0$,

$$[\hat{V}(0) - \hat{V}(1)] > [V^*(0) - V^*(1)] \tag{13}$$

and

$$\hat{d}_1 \leq d_1^*. \tag{14}$$

That is to say, when a decision-maker ignores the possibility of acquiring further information about the consequences of an irreversible development action, he inevitably understates the net advantage of preservation over development and prejudices the decision somewhat in favor of immediate development.

This does not mean that immediate development is necessarily the wrong decision. If $B_1 + (1 - p) \alpha > 0$. It is indeed optimal to go ahead with full development now despite the irreversibility and despite the possibility of acquiring further information later. AF never attempted to deny that this might be the outcome:

> Just because an action is irreversible does not mean that it should not be undertaken. Rather, the effect of irreversibility is to reduce the benefits, which are then balanced against costs in the usual way. [1, p. 319]

Where we do agree with Freeman is his interpretation of V_q as "not a magnitude which can be estimated separately" and as "a product of an appropriately structured decision analysis rather than as an input to the analysis" [4, p. 294]. Quasi-option value is not a separate component of benefit in the sense, say, that existence value is separate from use value, provided the benefit analysis is done correctly, i.e., provided the analyst takes proper account of the implications of prospects for gaining information. The only additional point we wish to make is that there is a common tendency in benefit cost analysis to replace random variables with their expected values, and this will result in error when future decisions can be delayed until after the resolution of the uncertainty. The needed correction is quasi-option value as defined by AF. Elsewhere we have shown that the magnitude of this correction is substantial in some plausible cases [2, 3].

DEPENDENT LEARNING

So far we have treated information about the consequences of development as though it arrived automatically with the passage of time. This is unrealistic, of course. The acquisition of information usually requires the expenditure of resources and occurs only if some agent takes appropriate action. Indeed, if the cost of the information exceeds $[\hat{V}(\hat{d}_1) - V*(d_1^*)]$, the expected value of the information, then it is not optimal to invest in acquiring it. While the cost of information must certainly be recognized along with the benefits, this does not invalidate our conclusions about quasi-option value.

Instead, the crucial distinction is between those cases in which the act of development itself generates information and those in which it does not--i.e., the acquisition of information is a separate decision. We refer to the former as dependent learning and the latter as independent learning. The conclusions stated above apply generally to independent learning. Freeman and Miller and Lad are correct in pointing out that they do not apply to dependent learning. It surely requires no algebra to show that, if information about the consequences of an irreversible development action can be obtained only by undertaking development, this strengthens the case for some development.

The practical importance of this observation depends on the answers to two empirical questions. Is it true that the information can be obtained only by undertaking development? How much development is required in order to obtain the information? With regard to the first question, we can certainly imagine a set of circumstances in which it must be answered in the affirmative. Suppose the uncertainty concerns the future economic benefits of development as opposed to its future environmental costs. In the case of oil extraction off the

California coast, for example, there may be uncertainty as to whether the offshore structures contain oil in commercial quantitites. In this case it is likely that the uncertainty can be resolved by undertaking some development--i.e., by drilling exploratory wells. However, we do not believe that this example is representative of many of the development decisions to which the concept of quasi-option value has been applied where the major uncertainty appears to pertain instead to the environmental costs of development or the benefits of preservation. That uncertainty is typically resolved not by undertaking development but by mounting some type of scientific research program--for example, biological research on the medicinal properties of indigenous plant species. We do not claim that research is costless and information arrives without conscious planning or effort. Our point is that information is often not generated by the development itself but requires a separate action. Of course, the fact that a tract is being considered for development may arouse popular interest and provide the stimulus for initiating a research program on the benefits of preservation. But the research can be conducted independently of the development, and the information flows from the research not from the act of development. If this is so, this is an example of independent learning as far as the development decision is concerned; and our earlier conclusions hold.

Even if one grants the hypothesis of dependent learning, the policy implications depend crucially on the precise manner in which development generates the information--i.e., on the form of the "information production function." Freeman assumes, for example, that there is no information if one does not develop initially; but if there is any development at all, the information is obtained. Several results follow from this assumption. In may be a less extreme type of diminishing returns; and an intermediate level of development between ε and 1 may be optimal. We certainly do not wish to claim that dependent learning never occurs or that, when it does, recognition of this fact invariably leads to less development than when it is disregarded. Our point is, first, that the occurrence of dependent as opposed to independent learning is an empirical question, and we believe that the latter is often the more relevant concept. Second, if dependent learning applies, the practical implications for development policy depend crucially on the degree of diminishing returns embodied in the information production function.

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