Option and Non-Use Values of Environmental Assets

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Abstract

It is widely recognized that the value of environmental assets such as biodiversity, unique locations and the atmosphere may be hard to quantify. In particular, *option values, quasi-option values* and *non-use values* have been the subject of extensive discussion. We propose here an evaluation of environmental assets based on the option value or shadow price associated with intertemporal welfare maximization under conditions of uncertainty about the future preferences. We show that these values can provide powerful motives for conservation of the goods, and are under certain conditions equivalent to a reduction in the discount rate to be applied to future benefits. We also show that the option value can be bounded below by a function of the degree of risk aversion and parameters of the probability distribution governing the uncertainty about future preferences.

JEL Classification: Q 20, D 80

Keywords: option value, irreversibility, non-use value, unique environmental asset, uncertainty about preferences.

Contents

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1 Introduction

The valuation of environmental resources such as biodiversity, current climate conditions, or complex ecological systems, has attracted attention for several decades. Amongst the earliest studies of these issues were Weisbrod [14], Krutilla [10], Cicchetti and Freeman [3], Arrow and Fisher [1] and Henry [8] [9]. Subsequent works that built on these contributions include Bishop [2], Smith [12], Krutilla and Fisher [6], Fisher and Hanneman [5] and Mitchell and Carson [11]. In this literature, a key question was how to allow for irreversibility, i.e., for the fact that certain options have the property that if they are once foreclosed, then they are never again available. The destruction of unique assets such as an historic building or an ecosystem, or the extinction of a species, have this characteristic. If we decide not to keep the building or the ecosystem or the species, then we can never subsequently change our minds. In contrast, if we decide not to build a new building, then we can usually change our minds at a subsequent date. If we are uncertain about our future preferences, then this possibility provides a type of insurance. This insurance is not available if the irreversible decision is carried out. Consequently the decision not to destroy a building or a species, or in general not to take an irreversible action, has to be credited with an *option value* or insurance value which reflects the value of keeping the alternative available for possible exercise in the future. In the current climate of concern about sustainability as an objective for environmental policy (see Solow [13], the Brundtland Report [15]) there is particular sensitivity to the thorough analysis of irreversible decisions with respect to the environment. Solow [13] argues that an important element in a formal interpretation of sustainability is an attempt to allow for the possibility that future generations may have very different preferences from ours about environmental assets. This possibility is modeled formally here and is at the heart of our analysis.

A concept related to option value is that of *non-use value.* Existence values and bequest values have been analyzed as categories of non-use values. There may be environmental goods for which we have no immediate economic use, whose existence we nevertheless value. Presumably the existence of certain species are in this category: the Californian condor, the spotted owl, and various snails and fish come to mind. There is no sense in which we can currently use these species: possibly one could argue that the condor and the owl have value as consumption items for those who make the effort required to view them, but few people come into this category, and one doubts that this is a significant issue with the snail.

These two concepts - option value and non-use value - seem to overlap. Many goods which exemplify one also exemplify the other. At the same time, there are no doubt differences. Non-use values may stem in some degree from ethical considerations, from a recognition that a species has a right to exist even if humanity places no direct value on it. But one suspects that behind many non-use valuations there lurks an option value: many non-use valuations stem from an unstated belief that at some date in the future and under certain conditions our preferences may change and a use value may emerge.

Our aim in this paper is to develop a simple continuous-time stochastic dynamic framework within which we can derive a formula for option values. This framework is derived from that introduced in Dasgupta and Heal [4]. We do this using a dynamic optimization model in which current planners are uncertain about the preferences of future generations, and wish to respect the possibility of their having a stronger preference for an environmental good. The model therefore admits a possibility of a change in preferences at some future date that will increase the valuation of an environmental good. This possibility of a change in the valuation of the environmental good in the future gives rise to an increase in the shadow price associated with the constraint on its availability: we interpret this change in the shadow price as an option or non-use value. We are able to calculate a bound on this value and show how it depends on the society's degree of risk aversion, on the parameters of the probability distribution governing the possibility of a change in preferences, and on the intensity of the possible shift in preferences. We are also able to show that this value is in a certain sense equivalent to a reduction in the discount rate to be applied to benefits from the environmental good in the future (Proposition 2).

The motivation for the existence of an option value in our model - the possibility of a shift in preferences in the future - is in the tradition established by Weisbrod [14] and the earliest writes on this subject. Mitchell and Carson [11] in a recent survey state that "option value is the amount that people will pay for a contract which guarantees them the right to purchase a good for a specified price at a specified point in the future, and may be thought of as a risk premium to compensate for uncertainty about future taste, income or supply." However, the framework within which we approach this is new. We study a continuous time dynamic optimization problem with the possibility of a stochastic change in preferences, and analyze the impact of the possibility of a change in preferences towards an environmental good. In particular, we ask how the uncertain possibility of a preference shift affects consumption rates and shadow prices for the environmental good. We compare the shadow price of the good in the presence of a possible future preference shift with that without such a possibility, and argue that the difference is an option value. In the words of Mitchell and Carson cited above, it is certainly "a risk premium to compensate for uncertainty about future taste, income or supply." It is not however "the amount that people will pay for a contract which guarantees them the right to purchase a good for a specified price at a specified point in the future", but rather the amount that they are willing to pay today for a unit of the good that can be held into the future. This approach succeeds in integrating the concept of option value into the mainstream economic literature on valuation by interpreting it as the difference between the shadow price of an irreplaceable asset calculated in two alternative frameworks, one with and one without the possibility of a change in preferences towards the asset in the future.

2 Optimal Conservation Decisions with Uncertain Future Preferences

2.1 The Basic Framework

Consider an environmental good of which there is at time t a stock S_t. This good may be consumed at a rate c_t, so that the rate of change of the stock is given by

$$\frac{dS_t}{dt} \equiv \dot{S}_t = -c_t \tag{1}$$

Feasibility requires that $S_t \geq 0 \ \forall t$. At time zero society derives utility from the consumption of this good according to the function $u(c_t)$ which is assumed to be increasing, twice continuously differentiable and strictly concave. There is a possibility that at a future date which we shall denote T the utility of consuming this good will change from $u(c_t)$ to $U(c_t)$ where $U(c_t) > u(c_t) \ \forall c_t$. In fact it is appropriate to think of U as very much bigger than u for all consumption levels. U is also assumed to be increasing, twice continuously differentiable and strictly concave. The date T at which there is a switch from u to U is a random variable with marginal density ω_t, so that $\omega_t > 0$ and $\int_0^\infty \omega_t \leq 1$. We permit inequality here as we wish to be able to recognize a positive probability that the change in preferences will never occur. We can think of the switch from u to U as representing a change of tastes from one generation to another: we are therefore envisaging the current generation as being uncertain about the preferences of its successors and wishing to allow for the fact that they may value more highly the environmental good.

The basic idea, then, is that there is a possibility of a change in preference that will lead to a great increase in the valuation of the environmental good. It is not certain that there will be such a change, nor do we know when it might occur. The question that we pose is: How does this possibility affect our use of the resource and our valuation of the resource?

In order to answer this question, we need first to formulate an ancillary problem. Following Dasgupta and Heal [4] we define

$$W(S_T) = Max \int_T^\infty U(c_t)\, e^{-\delta(t-T)} dt$$
$$subject\ to \int_T^\infty c_t dt = S_T$$

$W(S_T)$ is thus state valuation function which values the stock S_T remaining at time T when the change in preferences occurs. Here of course δ is a discount rate applied to future utilities: for a discussion of the appropriateness of discounting in this context see Heal [7]. Given this, we may now define an overall problem:

$$\begin{array}{c} Maximize \int_0^\infty \omega_T \left\{ \int_0^T u(c_t) e^{-\delta t} dt + e^{-\delta T} W(S_T) \right\} dT \\ subject\ to\ \dot{S}_t = -c_t\ and\ S_t \geq 0 \forall t. \end{array} \tag{2}$$

The interpretation of this problem is as follows. The date T at which preferences may change is a random variable. For any particular T, the utility of a consumption path is given by the expression in the parentheses $\{\}$. We then take the expectation of this over all possible values of T as the maximand. In other words, we maximize the expected discounted value of utility derived from consuming the environmental good, where the expectation is taken with respect the probability distribution governing an increase in preference for the environmental good. By integrating by parts, the problem (2) can be reformulated as

$$\begin{array}{c} Maximize \int_0^\infty e^{-\delta t} \{ u(c_t) \Omega_t + \omega_t W(S_t) \} dt \\ subject\ to\ \dot{S}_t = -c_t\ and\ S_t \geq 0 \forall t. \end{array} \tag{3}$$

where $\Omega_t = \int_t^\infty \omega_\tau d\tau$.

2.2 Consumption Rates and the Option Value

In order to solve problem (3) we introduce a shadow price or adjoint variable on the stock S_t: this will be denoted p_t. Then a necessary condition for a consumption path and a shadow price path to solve (3) is that c_t and p_t satisfy the following equations[1]:

$$\begin{array}{c} u'(c_t) \Omega_t = p_t \\ \dot{p}_t - \delta p_t = -\omega_t W' \end{array} \tag{4}$$

where a prime denotes the first derivative of a function of a single variable with respect to its argument. A little manipulation allows us to condense (4) into the intuitive single equation

$$\eta \frac{\dot{c}_t}{c_t} = \delta + \left\{ \frac{u' - W'}{u'} \right\} \frac{\omega_t}{\Omega_t} \tag{5}$$

where η is the elasticity of the marginal utility of the function u with respect to consumption, i.e., $\eta = \frac{u''c}{u'} < 0$ where the double prime denotes the second derivative of u with respect to its argument. (5) tells us that the rate of change of consumption depends on the discount rate, the elasticity of the marginal utility of consumption and the expectation of the increase in the marginal valuation of consumption conditional on the change in preferences not having yet occurred. ($\frac{\omega}{\Omega}$ is of course the probability of the change in preferences occurring at t given that it has not previously occurred.)

[1] For mathematical details, see Dasgupta and Heal.

In order to interpret (5) it is helpful to consider a conventional optimal resource use problem with no possibility of a change in preferences. This problem can be formulated as

$$\begin{array}{c} Maximize \int_0^\infty u(c_t)\, e^{-\delta t} dt \\ subject\ to\ \int_0^\infty c_t dt \leq S_0 \end{array} \tag{6}$$

For this problem (6) the equivalent to equation (5) is:

$$\eta \frac{\dot{c}_t}{c_t} = \delta \tag{7}$$

A comparison of (5) and (7) shows clearly the effect of the possible change in preferences for the environmental good. We expect that $u' - W' < 0$, so that in moving from (7) to (5) we lower the effective discount rate. This is to be expected, and is stated formally in Proposition 2 below: the possibility of an increase in our preferences for the good in the future makes us more future-oriented in our selection of a consumption rate. First we note:

Remark 1 *On a path satisfying (5) the initial level of consumption is less than the initial level of consumption on a path satisfying (7).*

Proof. Denote the paths satisfying (5) and (7) by $c_t(5)$ and $c_t(7)$ respectively. We know that $\dot{c}(5)/c(5) > \dot{c}(7)/c(7)$. Hence $c_0(5) < c_0(7)$. This follows from the fact that both paths satisfy the same integral constraint on consumption•

The consumption profile is more "sustainable", at least in the sense of showing less inequality between generations, on the path with the possibility of a change in preferences. We can now assert:

Proposition 2 *The possibility of an increase in the valuation of the environmental good, as represented by a shift from u to U at a date T with distribution ω_t, leads to a more conservative initial usage policy for the good and a more egalitarian consumption pattern over time. The possibility of a future change in preferences is equivalent to the reduction of the discount rate δ in the non-stochastic optimal use problem (6) by the time-dependent amount $\left\{\frac{u'-W'}{u'}\right\}\frac{\omega_t}{\Omega_t}$.*

In more informal terms, we have shown that the conditions that give rise to an option value, also lead to a more conservative depletion policy. Next we study the effect of these conditions on the shadow price of the environmental good.

2.3 Option Values and Shadow Prices

We assume in this section the utility function u has a constant elasticity of marginal utility with respect to consumption. This, plus specific assumptions about the distribution ω_t, allows us to characterize partially the change in the shadow price of the environmental good as a result of the introduction of the possibility of a preference change. We shall identify this change in the shadow price as the option value. In this case if we take the certain problem whose solution satisfies (7) then it is routine to show that

$$\bar{c_0} = \frac{-S_0\delta}{\eta} \tag{8}$$

where a bar over a variable denotes its value along a solution path to the certain problem. We cannot obtain a similar formula for c_0 on the path satisfying (5): however we can obtain a bound. We assume that the distribution ω_t is a Poisson distribution with parameter λ so that $\frac{\omega_t}{\Omega_t} = \lambda \ \forall t$. In this case (5) becomes

$$\eta \frac{\dot{c}_t}{c_t} = \delta + \left\{ \frac{u' - W'}{u'} \right\} \lambda \tag{9}$$

With our strict concavity assumption on preferences, both u' and W' rise over time as the remaining stock and the level of consumption both fall. Define $b = \inf_t \left\{ \frac{u'(c_t) - W'(S_t)}{u'(c_t)} \right\}$ and assume that there exists a strictly negative number ϵ such that $b < \epsilon < 0$. This would certainly be true if for any S_t and the associated c_t along a path satisfying (9) W' were strictly greater than u'. If U is much greater than u, this is likely to be the case. Hence

$$\delta + \left\{ \frac{u' - W'}{u'} \right\} \lambda \geq \delta + b\lambda \tag{10}$$

Letting $\delta + b\lambda = \delta^* < \delta$, and applying remark 1 above, we know that

$$c_0 < \frac{-S_0\delta^*}{\eta} \tag{11}$$

Comparing (8) and (11) we see that $c_0 < \bar{c_0}$. Assume that $\int_0^\infty \omega_t = 1$, so that the preference change will occur with certainty at some finite date. Let p_0 and $\bar{p_0}$ be the initial shadow prices on the paths satisfying (5) and (7) respectively, i.e., the initial shadow prices of the environmental good with and without the possibility of a preference change. Then we can assert:

Proposition 3 *Assume that $\int_0^\infty \omega_t = 1$, and that the utility functions have constant elasticity of marginal utility. Then the initial shadow prices of the environmental good with (p_0) and without ($\bar{p_0}$) the possibility of a shift of preferences towards the good in the future satisfy the inequality*

$$p_0 > u'\left(\frac{-S_0\delta^*}{\eta}\right) > \bar{p_0} = u'\left(\frac{-S_0\delta}{\delta}\right) \tag{12}$$

If $u(c) = \ln c$, then the change in shadow price or option value satisfies the following inequality:

$$\frac{p_0 - \bar{p_0}}{\bar{p_0}} > 1 - \frac{\delta}{\delta *} = \frac{-b\lambda}{\delta} \tag{13}$$

More generally, if $u(c) = -c^{\eta}$, $\eta < 0$, then

$$\frac{p_0 - \bar{p_0}}{\bar{p_0}} > 1 - \left(\frac{\delta}{\delta + b\lambda}\right)^{\eta - 1} \tag{14}$$

Proof. The inequality (12) follows from (4) and (8). One verifies (13) by noting that if $u(c) = \ln c$, then $u'\left(\frac{-S_0\delta^*}{\eta}\right) = 1/S_0\delta = p_0$. (14) follows from the fact that $u(c) = -c^{-\eta}$ implies $u' = -\eta\left(\frac{-S_0\delta}{\eta}\right)^{\eta-1}$ whence $\frac{p_0 - \bar{p}_0}{p_0} > \frac{-\eta\left[\frac{-S_0\delta^*}{\eta}\right]^{\eta-1} + \eta\left[\frac{-S_0\delta}{\eta}\right]^{\eta-1}}{-\eta\left[\frac{-S_0\delta^*}{\eta}\right]^{\eta-1}}$ •

3 Conclusions

We have analyzed the problem of making irreversible decisions is a situation where preferences may change in the future, after the irreversible decision has been made. Following Weisbrod [14], Krutilla [10], Arrow and Fisher [1], and Henry [8], we have used this as a framework for thinking about the conservation of environmental assets such as biodiversity, unique locations, ecosystems, the atmosphere, etc. We have worked with a model in which there is a possibility of a quantum increase in the intensity of preference for environmental goods at an unknown future date. The present generation does not know the preferences of its successors and wishes to allow for the possibility of them having a greater valuation of the environmental good. Solow [13] interprets the desirability of sustainability as arising from an obligation to leave our successors the opportunity to be as well off as we are. On this interpretation, policies oriented towards sustainability must be based on a recognition of the possibility that our successors may have different preferences from us. Hence the approach here may be a building block towards a broader analysis of sustainability.

We have studied the change in the shadow price of the environmental asset as a result of the possibility of a preference change and identified this with the concept of option value. We were able to find a lower bound on this which increases with λ, the exponent of the Poisson distribution describing the possibility of a preference change. An increase in the degree of risk aversion η, measured by the elasticity of marginal utility, also increases the lower bound on the option value. This lower bound also depends in an increasing way on b, the lower bound on the increase in the marginal valuation of the good along an optimal use path. Note that if the increase in the marginal valuation were always equal to its lower bound - i.e., $b = \left\{\frac{u'(c_t) - W'(S_t)}{u'(c_t)}\right\} \forall t$

- then the lower bound on the change in shadow price would in fact be equal to the change in shadow price, i.e., would be an exact estimate.

In order to asses the potential importance of the effects that we have analyzed, it is instructive to review the numerical size of the change in the shadow price resulting from some possible parameter values. Consider for simplicity the case of $\eta = -1$, so that the utility function is logarithmic, and let $\delta = 0.08$, $b = -1$ and $\lambda = 0.05$. This is a very conventional discount rate, and a relatively small lower bound on the increase in marginal valuation b, implying that W' is always at least twice u'. Then from (13) we see that $p_0 = 8p_0/5$. The possibility of a preference change raises the shadow price by at least 37.5%. Halving the discount rate from 10% to 5% would double this lower bound, to 75%. Halving b would of course halve the lower bound. If instead we take $\eta = -2$, then for the same parameter values we have $p_0 = 512\ \bar{p_0}\ /27$. Clearly the orders of magnitude involved are quite large, and are sensitive to the degree of risk aversion.

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