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POLISH ACADEMY OF SCIENCES, SZCZECIN DEPARTMENT
AGRICULTURAL UNIVERSITY OF SZCZECIN
FACULTY OF ECONOMICS AND ORGANIZATION OF FOOD ECONOMY

MODELLING OF ECONOMY IN SPECIALLY PROTECTED REGIONS

Proceedings of the international conference held on 9-11 june 1994 in Drawno, Poland

SZCZECIN 1994

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OPTION AND QUASI-OPTION VALUES: A CRITICAL ASSESSMENT

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1. Introduction

As long as natural assets are involved in a given project proposal, uncertainty and irreversibility about the consequences of a given alternative are pervasive characteristics of the decision making process. If this is the case, standard cost-benefit analysis techniques (i.e. performed under certainty and perfect knowledge hypothesis) may lead to invalid conclusions. During the last two decades, following the raise of the so called "total economic value" paradigm, several authors tried to take into account the characteristics of decision making process into cost-benefit analysis, by means of option value and quasi-option value concepts. Unfortunately, the distinction between the two has been the subject of a considerabele confusion in the literature. Thus the aim of this paper is to clarify their conceptual differences and their theoretical and empirical relevance.

2. The total economic value paradigm

Total Economic Value (TEV) can be derived in a household production function framework. We can imagine the representative family facing an expenditure minimizing problem, subject to a minimal utility level constraint and to a technology constraint, as follows:

$$\min_x E = \mathbf{p}\mathbf{x}$$

$$s.t. \quad U = f(z) \geq U^0 \tag{0.1}$$

$$z = g(x, q \mid T)$$

where $\mathbf{x}$ is a vector of market goods or services, $\mathbf{p}$ is the price vector associated to $\mathbf{x}$, q is a variable representing the natural resource under examination and T is the household's production technology. The problem solution is the expenditure function $E^0(\mathbf{p}, q, U^0)$, whose first derivative with respect to q yield s an inverse compensated demand function for q:

$$\frac{\partial E^0}{\partial q} = -E^0_q(\mathbf{p}, q, U^0) \tag{0.2}$$

The natural resource value at q^0, the initial (current) level, for the i-th family is

$$V_i = -\int_o^{q^0} E^0_q(\mathbf{p}, q, U^0)dq, \tag{0.3}$$

which aggregated across all families at each time, discounted and integrated across time, yields the total economic value of the natural resource:

$$TEV = \int_i \int_0^{\infty} V_i(t)e^{-rt}\, dt. \tag{0.4}$$

Three main remarks are in order. First, current values, $V(0)$, are only a minor portion of the time stream values $V(t)$; the remaining values will accrue in the future only. Second, neither the utility function, $U = f(z)$, nor the activity production function, $z = g(\mathbf{x}, q \mid T)$, places any prior restrictions on the kinds of activities that may generate utility and value[1]. Third, the household production function depends on the househlod's activity production technology, which is subject to augmentation or degeneration over time[2].

During the last two decades, the debate on how define and evaluate components of TEV was probably the most intriguing one in the natural resource economics field. However, today there is some agreement about the following components taxonomy.

In general, any activity produced in a process such $z = g(\mathbf{x}, q \mid T)$, in which q is combined with one or more elements of the $\mathbf{x}$ vector, may generate a first group of values, the so-called "use values". Where q and some element, x_j, of the $\mathbf{x}$ vector are weak complements in production of a particular activity, it is in principle possible to estimate the use values associated with that activity by analizing data generated by transactions in the market for x_j (*Mäler, 1974; Freeman, 1979)*. It is necessary to distinguish among four classes of use values, on the basis of the timing of the use decision (past or future), the uncertainty that attaches to future use, and the value that attaches to delaying irriversible decisions about use if information is expected to become available later:

[1]These include current observable on–site use values, where q is combined with purchased commodities such as travel, accommodation, and complementary equipment. However, total value may also include off-site or vicarious uses, the anticipation of future use, and the value obtained from the simple knowledge that the environmental asset continue to exist.

[2]This explicitly recognizes the development of skill in activity production through conscious aquisition of information and instruction and through a less deliberate process of "learning by doing".

(a) "current use values" are observable *ex post* (i.e. after the use decision has been made): this kind of values are amenable to valuation techniques founded upon the assumption of weak complementarity, i.e. the travel cost method (*Clawson, 1959; Clawson and Knetsch, 1966*) and the hedonic price method (*Griliches, 1971; Rosen, 1974*);

(b) expected value of future use is *ex ante* (i.e. the irrevocable use decision is yet to be made), uncertain and subject to change as new information becomes available: this value, often called "expected surplus" may be projected from studies of *ex post* use values or estimated in contingent valuation studies of *ex ante* use;

(c) (ordinary) "option value" is ex ante and emerges when a risk averse individual faces an uncertain future: it is the risk premium the individual may be willing to pay, beyond expected surplus to ensure future availability of the resource: option value can be estimated only via contingent valuation exercises;

(d) "quasi-option value" emerges in the context of preservation vs. development decisions, when there is some expectation about future information availability: It is the expected value of perfect information conditional on having made the most flexible choice (i.e. less irreversible) in the present.

A second group of values, the so-called "existence values", may be generated simply by knowing that the environmental asset exists. The activity production technology generating these values is a process like $z = g(0, q \mid T)$, which is a special case of the household production function in which x=0, i.e. existence values for q are generated by q alone (no elements of the **x** vector are involved in the current time period). Because any kind of use (current and future) is excluded, existence values must be altruistically motivated: intergenerational altruism (i.e. bequest motivations), interpersonal altruism (i.e. benevolence towards friends and relatives), environmental ethics (i.e. sympathy for people and animals, environmental responsability, etc.). It seems clear that existence values can be estimated only via contingent valuation techniques, because the weak complementarity condition does not operate.

As far as uncertainty (and irriversibility) about consequences of a given project alternative is the most relevant character of environmental projects proposals, the focus is on option and quasi-option values. Unfortunately the distinction between (ordinary) option value and quasi-option value has been the subject of a considerable confusion in the literature. I will try to clarify their conceptual differences and their theoretical and empirical relevance in the next sections.

3. Option value and quasi-option value: a definition

3.1. Cost-Benefit analysis under uncertainty

As known, the welfare theoretical justification for comparing benefits and costs is the s.c. "potential Pareto improvement" criterion, operationally known in the cost-benefit analysis literature as "compensation test". Current practice is to conduct this exercise as if gainers and losers from a proposed project are operating under certainty. But what are the changes we should apply to cost-benefit analysis if unceratinty is working? Early writers did advocate adjustements in the discount rate to reflect uncertainty[3]; today the theory tends to focus on the compensation test itself (*Ulph, 1982*).

A first possibility is termed the "ex post compensation test", under which a project is deemed economically feasible if the gainers can fully compensate the losers in all the state of the world. Another possibility is the "ex ante compensation test", which examines whether ex ante gainers (those with higher expected values of utility under the "with project" scenario) can compensate ex ante losers (those with lower expected utility). The third possibility is termed the "expected compensation test", under which a project passes the test if the sum of the expected wilingness to pay across all gainers (those showing a positive WTP for the project) and losers (those showing a negative WTP) is positive.

Out of the three welfare criteria discussed so far[4], the ex ante compensation test is preferred. In fact, the ex post test seems to be operationally difficult to implement because it is practically impossible to evaluate benefits and costs in all conceivable future states of the world. On the other side, the expected compensation test neglects the fact that proposals not only provide goods and services, but also affect people through the uncertainty they feel. Stated differently, the ex ante compensation test is theoretically more correct because it takes into account adjustments for this uncertainty: this adjustment is option value.

Finally, two cautions should be pointed out: (a) the discussion about the theoretical relevance of different compensation tests sheds no lights on the distributional issues regarding cost-

[3]This has continued to be a controversial suggestion, and more recent writers have tended to strengthen the theoretical argument for the riskless rate of discount (see, among others, Arrow and Lind, 1970; Graham, 1981)

[4]The proposed compensation tests do not exhaust all possibilities: for example, a further measure of value may be based upon the s.c. "fair bet point" (Graham, 1981).

-benefit analysis decisions; (b) proposals that pass the ex ante compensation test and are judged to have acceptable distributional implications may still be rejected if, under some plausible future scenarios, unacceptably large negative ex post net benefits could occur (*Bishop, 1978*).

3.2. Option value

Weisbrod (1964) was the first to define the concept of option value (OV). According to his interpretation, OV is essentially an expression of preference, a WTP for the preservation of a natural asset against some probability that the individual will make use of it at a later date. The essential feature of OV is the presence of uncertainty: OV is a risk premium a risk averse individual is willing to pay to resolve uncertainty regarding the future demand or supply of the natural asset under examination.

Following *Graham (1981)*, OV is equal to the difference between the maximum state independent payment (ex ante money measure) would the individual agree to, i.e. option price (OP), and the state dependent payment (the mathematical expectation of ex post payments, contidional to the future states of the world), i.e. the expected surplus (E[S]):

$$OV = OP - E[S]. \tag{0.5}$$

From this definition it is clear that OV is derived in a timeless framework: this is an essential feature that differentiates the OV, which is a static concept, from the quasi-option value, which is an instrinsically dynamic construction.

There has been considerable controversy, since the *Schmalensee (1972)* article, as to whether OV may take a negative value, in contrast to the positive value assumed by early writers *(Weisbrod, 1964; Cicchetti and Freeman, 1971)*. The problem is that there are two kinds of risk: demand risk, in which a purchased option would prove useless if future demand did not eventuate *(Hartman and Plummer, 1986)*, and supply risk, in which future availability is not assured unless the option is purchased *(Bishop, 1982)*. Only in the case where demand is certain and supply uncertain can we be assured that, for a risk averse individual, OV>0 and OP>E[S].

3.3. Quasi-option value

A different concept, the s.c. quasi-option value (QOV), has been advanced independently by *Arrow and Fisher (1974)* and *Henry (1974)*. Under uncertainty, whenever it is assumed that a given decision may have (at least in part) irreversible effects and that there is some prospect of learning after a decision has been taken, it is generally valuable to keep open an option even in case of risk neutrality.

Notwithstanding the misleading name, the theory of QOV should be considered as the most general approach to intertemporal flexibility and environmental preservation under uncertainty, since it is relevant whenever there is at least two options whose consequences have diferent degrees of irreversibility (perfect temporal symmetry would obviously be an extreme case), and whenever learning is possible before future choice will be made (the impossibility of learning would be a very extreme hypothesis)[5]. Unlike OV, QOV emerges in a sequential decision problem, whenever this problem cannot be reduced, even in principle, to the choice in the first period of the optimal contingent

[5] Another magnitude conceptually close to QOV is the "value of waiting", which is analyzed mainly in order to choose the optimal starting time of a new project (McDonald and Siegel,1986).

strategy.

The main results of the debate on QOV are: (a) the sign of QOV is positive under quite general assumption *(Smith, 1983; Fisher and Hanemann, 1987)*; (b) an increase in uncertainty would induce an increase in QOV *(Cabellero, 1991)* and would therefore encourage the preservation of the environment.

4. Theoretical and empirical relevance of OV and QOV

In the preceding section we pointed out that OV is the expression of a rational valuation under risk and that it is sensitive to individual's attitude toward risk, while QOV is expression of a rational valuation under uncertainty[6]. The OV is basically a static concept, altough its use could be extended to dynamic problems, whenever markets are complete and the decision problem is not a genuinely sequential one (see, for example, *Johansson, 1993*, chs. 7 and 8). The QOV is an intrinsically dynamic concept as it presupposes incomplete markets and a sequential decision problem which cannot be reduced to an equivalent non-sequential problem.

It should be emphasized that the concept of rationality underlying the received decision theory (relevant for the OV concept) and that underlying the existence of positive QOV are quite different. Expected utility theory rests on "substantive" rationality, as the decision maker is able to choose the optimal choice profile which, by definition, will never be regretted in the future, and intertemporal coherence is nothing but a corollary of such a concept of rationality. However, as soon as we assume un-

[6]Uncertainty characterizes a given decision whenever we cannot express a unique, additive, fully reliable probability distribution among the states of the world under examination.

certainty and irreversibility, substantial rationality does not apply: we may only adopt a conception of "procedural" rationality, as the optimal decision strategy may change as a consequence of learning and can only be approximated by periodical revising the sequence of choices according to a rationale rule *(Favereau, 1989)*.

A first step toward an assessment of theoretical and empirical relevance of OV and QOV is to recognize the general validity of the logical structure underlying the genesis of these two values. Indeed, it should be stressed the strict similarities existing between these two concepts and related concepts in other fields of economics. It could be worthwhile to remember that in monetary theory the distinction of the above-mentioned two kinds of rational behaviour (i.e. toward risk and toward uncertainty) was already quite clear thanks to *Keynes (1936)*, who distinguished between precautionary liquidity, related to probability (i.e. risk), and speculative liquidity, related to the weight of evidence (i.e. uncertainty), the former playing the role of a risk premium, the latter being best interpreted in terms of preference for intertemporal liquidity *(Hicks, 1974)*.

From an empirical point of view, even more important are similarities with the financial theory literature. Indeed, it should be stressed that a crucial point for an effective publication of cost-benefit analysis to project which could have environmental impacts is represented by getting a reliable monetary measure for OV and QOV. As a matter of fact, while there is a certain degree of agreement about how to get a monetary measure of OV via contingent valuation techniques *(Cummings et al., 1986; Mitchell and Carson, 1989)*, as far as now no reliable technique has been developed to get ex ante measures of QOV. Thus, the analysis of monetary and financial literature could help to develop a monetary measure of QOV, building on related measures for liquidity preference and negotiable financial options.

Unfortunately a recent survey carried on by *Basili (1992)* does not look very promising. According to this Author, "the measures suggested so far are only ordinal and are based on few arbitrary technical assumptions". Moreover, the illusion of an operational measure is obtained only by abstracting from subjective factors (see, for example, *Jones and Ostroy, 1984; Lippman and McCall, 1986; Pindyck, 1991)* which crucially influence figures, according to both theoretical and experimental considerations. Hovewer the approach in terms of stochastic processes surveyed and developed by Pindyck is a potentially fertile programme as far as OV is concerned: unfortunately the assumption of complete markets and risk seems to preclude an application of its application to QOV. The only financial measure which clerarly assumes uncertainty is the *Jones and Ostroy* one, which unfortunately is spoiled by a few technical shortcomings and by a rudimentary analysis of uncertainty. The subjective measures of financial option values (see, for example *Goldman, 1974 and 1978; Hahn, 1990)* are more robust from a theoretical point of view, but their application is so far limited to risk and exogenous learning: thus the insights which may be drawn from these measures are not easily transferred to the analysis of QOV.

Even though attempts to reach an empirical measure of QOV based on financial theory seem to face insormontable shortcomings (at least so far), some recent works *(Greenley et al., 1982; Albers et al.,* forthcoming) shed new light on the magnitude of this value, which is not negligible with respect to "certainty" figures. Thus these researches seem to reinforce the need to go ahead on the "QOV evaluation" road. Even more important is the role played by QOV in changing both the theoretical and the operational perspective we look at the cost-benefit analysis exercise. So far cost-benefit analysts have implicitly assumed that all decisions are equally irreversible when, in fact, this is not the case. The framework utilized to devise QOV is potentially very rich in insights about correct project evaluation procedures, optimal timing of investments, and optimal level of information gathering *(Miller and Lad, 1984)*.

5. Concluding remarks

Both option values examined so far play an important role in any assessment of environmental values for both theoretical and practical purposes, and provide the ultimate foundations for a rational policy directed towards the preservation of environmental resources.

The (ordinary) option value is relevant whenever uncertainty is soft (risk) and markets complete, as it reflects essentially risk aversion: in this case a more flexible option commands a risk premium because it is a safer store of value. The quasi-option value is relevant whenever markets are incomplete, uncertainty is hard (real uncertainty), and the decision problem is sequential: in this case a more flexible option, even under risk neutrality, commands a "reversibility" premium at the extent it allows the exploitation of prospective learning before subsequent decissions.

In the environmental field the QOV is particularly important because the uncertainty faced is tipically hard and irreversibility is very serious, involving very delicate sequential decision problems. Unfortunately, while to OV fairly precise measures may be assigned, particularly through survey techniques (i.e. contingent valuation approaches) or through methods developed in financial theory for financial options, QOV cannot be easily measured. All the measures suggested so far are only ordinal and, what is worse, the orderings of choices according to sequential flexibility, which gives the ordering of sequential option values (i.e. QOVS), is very sensitive to the specification of the model.

Notwithstanding all these shortcomings, the QOV theory has obtained some qualitative results which are quite important for the preservation of natural assets. First, it was established that, whenever QOV is positive, the traditional techniques for selecting the optimum choice and for analyzing problems characterized by uncertainty on the basis of the certainty equivalence approach cannot be used safely, because they underestimate the value of environmental resources. Second, it was proved that QOV is positive under quite general conditions, whenever uncertainty and irreversibility coexists, and learning is possible before future choices. Third, the value of QOV, given a certain degree of uncertainty and of irreversibility of choice, depends basically on the characteristics of prospective learning, on past learning (competence) and on the attitude towards uncertainty. In addition, coeteris paribus, it depends on the degree of irreversibility. Fourth, the QOV increases, under quite general conditions, with the degree of uncertainty. The growing awareness of our deep ignorance about the long term effects of the interaction between economic development and environment, as well as of their irreversibility, should induce a more cautious environmental policy.

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