SENSITIVITY OF VALUATION OF ENVIRONMENTAL RESOURCES TO TECHNOLOGICAL AND MARKET CHANGES

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Sustainable development requires satisfactory fulfillment of a group of criteria regarding the economic, environmental and social dimension of projects, while economic development is characterized by giving priority to the economic criteria. Often decisions to develop or conserve environmental resources are based solely on the criterion of economic benefit, as it is derived from the classical cost-benefit approach. The decision, though, to preserve the environment or initiate a development project most of time has to be taken with incomplete or uncertain knowledge of future conditions, results in irreversible loss of the environmental resource and may be postponed for a later time. These features suggest that in the case of environmental valuation the classical approach may not be sufficient. This paper presents the international literature on the common methods for the assessment of the total value of environmental resources (namely travel cost method, contingent valuation method and hedonic price method) and discusses the application of these methods to certain cases in Greece. Special attention is given to the different methodologies, developed recently in the field of environmental economics, for the assessment and estimation of the option value. A case study is presented where the selected methodologies are implemented to address the dilemma whether to develop a gold mine in Thrace or to preserve the existing natural environment. Sensitivity studies are reported concerning changes to technological and market conditions. This example of implementing valuation methodologies does not aim at providing a precise final result to support a decision towards development or towards preservation. Instead, it aims at demonstrating the robustness of potential decisions to variability of interest rates, demand for recreation, operational costs, commodity prices, etc. Ultimately, the contribution of this paper is to enhance structural thinking for taking account all hidden benefits from the protection and preservation of environment in the framework of sustainable development.

Key words: Environmental Valuation, Option Value, Environmental Management

INTRODUCTION

Sustainable development requires satisfactory fulfillment of a vector of various desirable social objectives (Pearce *et al.*, 1990). The elements to be included in the vector are open to ethical debate in each society, but a common approach is to use criteria regarding the economic, environmental and social dimension of projects. Often decisions to develop or conserve environmental resources are based solely on economic criteria, using the classical cost-benefit approach. In conventional economic analysis of projects environmental impacts are thought as (mostly negative) externalities and are not quantified and integrated in the cost-benefit analysis.

In most cases, though, the decision to preserve the environment or initiate a development project has to be taken under three fundamental conditions. First, knowledge of future conditions is incomplete or uncertain. Future returns can be described only in a probabilistic framework. Second, the development results in partially or completely irreversible loss of the environmental resource. Third the decision may be postponed for a later time until more information becomes available. These features suggest that in the case of environmental valuation the classical approach may not be sufficient (Dixit and Pindyck, 1994).

The Total Economic Value (TEV) of the environmental resources is a notion that earns more and more attention. Because of the nature of environment as a public good, when public works managers conduct cost-benefit analyses of projects, they have to take into account and assess the TEV. That is why the interest about methods to value environmental resources is growing.

It has been argued that a particular component of TEV called "option value" is likely to be significantly large and, thus, critical to the decision for environmental conservation. In Northern Greece there are a few outstanding sites, which may be facing the development challenge. It is thought and expected that, as income and education levels are increasing in Greece, the future demand for these sites in Northern Greece will increase quite substantially. In order to identify the true value of unspoiled outstanding locations, option demand theory may provide great help.

In general, the market conditions and technological changes affect the offer of services, the production and cost of products and more importantly the decisions taken by managers. Likewise demand for ecotourism may be subjected to variations due to unpredictable and uncertain technological and market changes. For example in Dadia National Forest Reserve the bird flu caused the number of ecotourists-visitors to decline by an impressive 50% in the year 1996 compared to the previous year's data. A new highway may provide easy access and shorten the travel time to the Reserve, increasing the number of visitors.

On the other hand, technological changes in equipment and techniques of extracting natural resources may make the extraction (e.g. gold mining) easier, with less pollution and operational cost for the manager. As a consequence, anticipation of a technological change may alter the time of the decision and postpone the development for a later time.

Lastly, the choice of the discount rate plays a dramatic role, especially in projects with environmental external costs. The discount rate may affect whether a project will begin or not or affect the timing of investment in projects under technological and revenue-related uncertainties.

In this paper an attempt is made to monitor the sensitivity of valuation to the increase or decrease of some factors like:

1. the operational cost or capital cost (here the TEV that is valued through the valuation methods of TEV),
2. market changes (here the volatility that the ecotourism presents), and
3. the discount rate (here the discount rate a manager will choose to assess an environmental resource).

The Dadia Forest Reserve is used as a case study for the estimation of option value, applying the Conrad (1997) model of option value theory.

TOTAL ECONOMIC VALUE

The economic value of environmental goods has a composite nature. There are of two main categories of *use* values and *non-use* values. Figure 1 depicts the concept of Total Economic Value. Use values are defined as those benefits associated with the actual use of the environment. Moreover the use values are classified as *direct use* and *indirect use* values. Additionally, economists have also introduced the concept of *option values*, that is, the additional value placed on a natural resource by those people who want to have the option of using the goods and services in the future (Bateman *et al.*, 2002; Markandya *et al.*, 2002).

Given appreciation of *all* values, measurements can be made to demonstrate the amount of public money that it may be feasible to allocate to the sustainable management of an environmental resource e.g. a wetland or forest. However, in many cases, non-use values are ignored and the total economic value of the resource can be severely undervalued. As a result, inadequate resources are fed into the management of environmental resources and environmental degradation occurs due to inappropriate commercial exploitation of the natural resource (Oglethorpe and Miliadou, 2000).

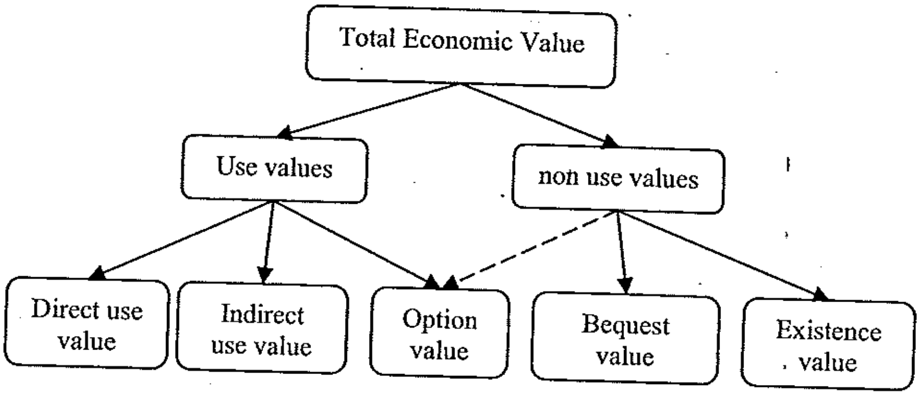

Figure 1: Total Economic Value

Several methods have been developed to express in monetary terms the value of environmental assets. The main economic valuation techniques are separated in two categories: the *revealed* preferences and the *stated* preferences.

In the *travel cost method* the estimation of value of non-market goods relies on travel expenditures incurred to visit a site. Visitors are being interviewed to determine the relationship between visitation rates and distance travelled. The observed variation in visitation rates and travel cost describes demand for the site. The demand function permits consumer surplus estimates of the economic value of the site (Krieger, 2001).

The *contingent valuation (CV) method* has been considered to be able to elicit types of benefits that other methods cannot elicit, and operates by creating a hypothetical market and using survey questions to elicit people's stated preferences for public goods. People are asked to express what they would be willing to pay or what they would be willing to accept for specified changes in environmental characteristics (Carson, 2000).

The *hedonic price method* uses existing markets – such as the housing or labour markets – to determine the value of an environmental good. The assumption is that property values or wages reflect a stream of benefits, some of which are attributable to the environmental good. On the other hand, hedonic pricing becomes problematic where alternative markets are distorted or where information about environmental products is not widespread and data are scarce (IUCN, 1998).

ENVIRONMENTAL VALUATION STUDIES IN GREECE

In recent years there is a growing number of papers and studies that make use of the above presented valuation techniques for environmental resources in Greece. Langford *et al.* (1998) undertook the first application of the contingent valuation method in

Greece and looked at WTP for protecting the Mediterranean monk seal (*Monachus monachus*) in the Aegean area.

Pavlikakis and Tsihrintzis (2003) present the decision-making from human opinion method (DeMHO) that can be used in Ecosystem management (EM) in selecting the more suitable and socially acceptable management plan, in order to protect or restore an ecosystem. The method focuses on the quantification of the human opinion, preferences and perceptions, which are investigated after research on the local population of the ecosystem. Multi-criteria decision-making procedures are then used to assign the appropriate weights and rank according to their importance the interest groups, the issues to be studied, and the alternative management plans. Continuing their research, Pavlikakis and Tsihrintzis (2007) concluded that for the local population biological factors such as flora and fauna and landscape aesthetics emerged as the most valuable ecosystem assets. Furthermore, the majority of those surveyed were willing to pay for the protection and the proper management of the park area. The mean value of WTP was ~36€ per respondent.

Kontogianni *et al.* (2003) examine the case of a WWTP in Thessaloniki, Greece, which is only partially operational and use the contingent valuation method to examine the willingness to pay of individuals to ensure the full operation of the WWTP, leading to significant improvements in the water quality of Thermaikos Bay. The average amount pledged of 15,23€ due every four months as an incremental increase in water rates matches the funding required to fully operate the plant.

Oglethorpe and Miliadou (2000) use the contingent valuation method to place a value on the non-use attributes of Lake Kerkini, a wetland area in northern Greece. They also examine the relationship between the revealed non-use values and the distance people live from the lake.

Also, Togridou *et al.* (2006) examined the influence of visitors' profile, information sources, environmental dispositions, and visit evaluation on visitors' willingness to pay (WTP) for the National Marine Park of Zakynthos. Regarding WTP amounts pledged, parameters of visit evaluation were the most significant predictors. The estimated annual revenue that could be gained could cover the operating costs of the Protected Area Management Body.

Birol *et al.* (2005) employ a choice experiment to estimate the values of changes in several ecological, social and economic functions that Cheimaditida wetland in Greece provides to the Greek public. The results reveal that there is considerable preference heterogeneity across the public and on average they derive positive and significant values from sustainable management of this wetland.

Skourtos *et al.* (2000) employ a mixed methodological approach, using questionnaire surveys of individuals and stakeholder focus groups to investigate economic values placed on a wetland surrounding Kalloni Bay on the island of Lesvos, Greece. Participants were asked to rate four possible development scenarios, their willingness to pay for their chosen scenario, and also series of attitudinal questions concerning the local environment and issues relevant to the area.

Michailides (2004) makes a priori socioeconomic valuation of great infrastructure works in Greece and especially of dams in conditions of uncertainty (water amount, unit price of water, technology etc). There is a case study of a dam for agriculture purposes in the region of Chalkidiki in Northern Greece and make use of the approaches of management risk and the irreversibility by using the theory of real options approach.

Papageorgiou and Vakrou (2001) make use of contingent valuation study and present the mean values of WTP of visitors in the National Parks of Mountain Olympus and Vikos-Aoos. Finally, Gatzoyiannis (2003) applies the contigent valuation method to assess the value of the suburban forest around Thessaloniki using questionnaires filled through the internet. He estimates a mean value of 303.934.103€ for the TEV of the forest, subject to uncertainties regarding the suitability of the regression model.

All of the above studies and their findings have serious policy implications for mapping public support for environmental improvements and assessing the availability of public monies for the protection and enhancement of the resource. The significance of this type of valuation studies is not so much the precise monetary figure assigned to the environmental resource, but rather the insight and the additional information they can provide to the decision-makers regarding the particular features of each resource and the public perceptions about it.

OPTION VALUE IN OPTIMAL STOPPING PROBLEM FRAMEWORK

Weisbrod (1964) used the term "option value" to describe the hidden non-use value that characterizes every good or service that has a double nature both as a public and as private good. Arrow and Fisher (1974) developed the notion of quasi-option value regarding the additional value that can come by postponing an irreversible action and integrating the additional information into the decision process. In the financial literature option valuation refers to techniques for pricing financial derivatives spurred by the works of Nobel prize winners Black, Scholes and Merton.

In recent years a number of authors have developed optimal stopping models to answer the basic question whether or not it is worth to the society to preserve an environmental resource (Reed, 1993; Conrad, 1997; Forsyth, 2000; Conrad, 2000; Buttle and Rondeau, 2004; Conrad and Kotani, 2005). Fackler (2007) commenting Conrad and Kotani's work, draws the attention to the limitations to the option valuation due to inadequate characterization of future uncertain prices of commodities (oil in this case), use an inappropriate discount rate and uncertain estimates of the TEV of oil reserves, as the last depends on many factors of the oil market (price shocks, oil's industry policies etc) and off course the technological change in drilling practice.

Conrad (1997) considers a tract of old-growth forest where the net value of standing timber is N dollars. The old-growth forest is assumed to yield a dividend in the form of an amenity flow, $A = A(t)$. Amenity flow represents the sum of non-timber benefits such as wildlife habitat, flood control and visitation, option and existence values. It is assumed that amenity value follows a process of geometric Brownian motion with mean drift rate μ and standard deviation σ. On the condition that it is impossible to recreate an old growth forest according to option theory there is a value function V=$V(A)$ and if preservation is optimal then $V(A)$ must satisfy an optimality condition

$$\delta V(A) = A + \left(1/_{dt}\right) E_t\left[dV(A)\right] \qquad (1)$$

where δ is the instantaneous discount rate, $E_t[]$ is the expectation operator at instant t and $dV(A)$ is the differential of the unknown value function.

Because A evolves stochastically taking the differential $dV(A)$ requires the application of Ito's Lemma. From the solution of the resulting differential equation, the critical amenity value A^* which would trigger the cutting of the old growth forest is found as

$$A^* = \frac{\alpha(\delta - \mu)N}{(\alpha + 1)} \tag{2}$$

with

$$-\alpha = (1/2 - \mu/\sigma^2) - \sqrt{(1/2 - \mu/\sigma^2)^2 + 2\delta/\sigma^2} \tag{3}$$

At the critical amenity value A^* the old-growth forest owner is indifferent between continued preservation and cutting. It is assumed that $\delta > \mu$, so that $A^* > 0$. If one can estimate μ, σ and N for a particular old-growth parcel, one could assign a value to δ and calculate the values for α and A^*.

CASE STUDY - SENSITIVITY ANALYSIS

The Dadia Forest Reserve in Greece lies in the Northern Eastern Greece near the Rodopi mountain range and is a place of rich biodiversity. Its flag species are the eagles and predatory birds. It is home to 36 out of 38 Europe's predatory bird species. There is also an Ecotourist Centre which is built in the local architectural style and has 20 rooms all with shower, heating and telephone. Amenities include a Restaurant, Coffee-shop, an Information / Conference Centre managed by WWF and a shop with specialized books, souvenirs and local products.

Table 1 shows the increase in the number of ecotourists and visitors of the Dadia Forest each year since 1994. Since 2000 the number of visitors has been stabilized to approximately 45.000 persons. At present no valuation study for the TEV of the Dadia Forest is available. Based on estimates of the total number of households in Greece, of the WTP per household, of the total number of visitors per year and of the WTP per visitor, it is estimated that the minimum and maximum amenity value is A_{min}=500.000€/year and A_{max}=17.500.000€/year respectively. A sensitivity analysis is performed for this wide range of amenity values.

Table 1: Number of ecotourists visitors to the Dadia Forest annually (in thousands)

Year	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*
Visitors	1,8	10,2	18,1	30,7	36,3	39,6	46,5	43,3	48,2	50,6	47,2	40,1

Source: Svoronou and Holden (2005)

Now, it is assumed that near the area of the forest of Dadia the opportunity exists to excavate a gold mine, similar to the one waiting for permits as filed by the Canadian company *Frontier Pacific Mining Corporation* in the nearby area of Perama Hill (http://www.frontierpacific.com/perama.php). The construction of a gold mine and the mining activities will disturb the ecological balance of the area resulting in irreversible loss of the annual benefits from preverving the Dadia Forest. The gold mine regardless of the duration of the mining activity is assumed to yield a constant lumped sum benefit N ranging from 120 to 240 million euros, as summarized in Table 2.

The nominal value of the interest rate δ is taken as 6%, subject to sensitivity analysis. The drift rate μ and the standard deviation σ of the geometric Brownian process underlying the Conrad (1997) model are estimated for the time series of the number of visitors (Table 1) as **0,4** and **0,5** for the transient case (data for the period 1994-2005) and as **0,01** and **0,12** for the steady state case (data for the period 1999-2005). The transient case seems to yield an unrealistic value for the drift rate due to the initial rush of visitors (according to Conrad's method it must be $\delta > \mu$, so that $A^* > 0$;

values of δ>0,40 are unlikely). Therefore only the steady state case is used in the sensitivity analyses (Tsagkas, 2007).

Table 2: Economic data for a gold mine in Perama Hill (conversion rate 1,00€=$1,25)

Capital Investment	$US 97.000.000 or 77.600.000€
Operating Cost	$171/oz or 137€/oz
Recoverable gold deposits	1.200.000oz
Market price of gold	300€/oz to 400€/oz
Total Operating Cost	(1.200.000oz*137€/oz =) 164.400.000€
Total Revenue	(1.200.000*300€/oz=) 360.000.000€ (1.200.000*400€/oz=) 480.000.000€
Net Benefit	(@300€/oz) ≈ 120.000.000€ (@400€/oz) ≈ 240.000.000€

In Table 3 the value of interest rate changes in the range 2% to 7% resulting in critical amenity values A^* from 1.5 to 11 million euros. This is the minimum annual revenue from the preservation of the forest reserve that will deter gold mining.

Table 3: Computation of A^* for μ=0,01 και σ=0,12 due to changes of the interest rate δ

δ	μ	σ	α	N	A^*
0,02	0,01	0,12	1,872	240.000.000 €	1.564.466 €
0,03	0,01	0,12	2,245	240.000.000 €	3.320.768 €
0,04	0,01	0,12	2,559	240.000.000 €	5.177.229 €
0,05	0,01	0,12	2,837	240.000.000 €	7.097.941 €
0,06	0,01	0,12	3,088	240.000.000 €	9.064.390 €
0,07	0,01	0,12	3,319	240.000.000 €	11.065.547 €

In Table 4 the values of the parameters μ and σ of the Brownian process representing the number of visitors to the park change in order to study how the volatility of recreation demand affects the critical amenity value A^*. Both in Tables 3 and 4 the net benefit from gold mining is set to its maximum value N = 240 million €.

Table 4: Computation of A^* for μ=0,01 και σ=0,12 due to volatility of ecotourism

δ	μ	σ	α	N	A^*
0,06	0,01	0,12	3,088	240.000.000 €	9.064.390 €
0,06	0,01	0,2	1,500	240.000.000 €	7.200.000 €
0,06	0,01	0,3	0,830	240.000.000 €	5.440.973 €
0,06	0,01	0,4	0,533	240.000.000 €	4.170.990 €
0,06	0,01	0,5	0,372	240.000.000 €	3.251.253 €
0,06	0,01	0,6	0,274	240.000.000 €	2.578.268 €
0,06	0,05	0,12	7,116	240.000.000 €	2.185.310 €
0,06	0,04	0,12	5,955	240.000.000 €	4.290.685 €
0,06	0,03	0,12	4,876	240.000.000 €	6.273.598 €
0,06	0,02	0,12	3,909	240.000.000 €	8.070.099 €

The net benefit is studied in Table 5, where N ranges from 130 to 360 million euros, keeping all other variables at their nominal values. According to the results in Table 5, the decision maker should favour the gold mining activity as long as the annual amenity for the Dadia Forest is less than ~4,9 or ~6,8 million euros for lumped sum net benefit from gold extraction equal to 130 or 240 million euros respectively. As expected from equation (2), the ratio N/A^* remains constant and equal to 26,47.

Table 5: Computation of A^* for μ=0,01 και σ=0,12 due to changes of net benefit N

δ	μ	σ	a	N	A^*
0,06	0,01	0,12	3,088	240.000.000 €	9.064.390 €
0,06	0,01	0,12	3,088	130.000.000 €	4.909.878 €
0,06	0,01	0,12	3,088	180.000.000 €	6.798.293 €
0,06	0,01	0,12	3,088	300.000.000 €	11.330.488 €
0,06	0,01	0,12	3,088	320.000.000 €	12.085.854 €
0,06	0,01	0,12	3,088	360.000.000 €	13.596.586 €

CONCLUSION-DISCUSSION

In this paper an attempt is made to monitor the sensitivity of option value for an environmental resource to the increase or decrease of some factors affected by technological or market changes, such as: a) the discount rate that will be used by a manager to assess an environmental resource, b) the operational cost or capital cost which affect the resulting net benefit from an investment and c) the uncertainty and volatility regarding future demand for ecotourism presents.

As it can been concluded from Tables 3, 4 and 5 the minimum annual revenue from ecotourism (critical amenity value of the environmental resource) decreases and, thus, preservation of the environment is favoured, if the discount rate decreases and the volatility of the number of visitors (defined as the ratio σ/μ) increases. On the other hand as the technological change and use of advanced extraction methods and tools may increase the net benefit from the mining activity, the required critical amenity value must also increase to save the environment. It appears, therefore, that technological innovation works against environmental protection.

However it should be mentioned that the factors affecting the amenity value were studied in isolation. It is likely that increases in net benefits due to intensified use of new technologies will improve the overall economy resulting in lower interest rates and higher demand for recreation. The effects of such correlations need to be studied further in detail.

The application of models for the estimation of option values is often difficult because the necessary time series of data are not available. Valuation methods are never capable to fully incorporate all benefits derived from the conservation of an environmental resource. Ultimately, the contribution of this paper is to establish, using the Conrad's (1997) model, a lower bound of the true value of the environment and enhance structural thinking for taking account all hidden benefits from the protection and preservation of environment in the framework of sustainable development.

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