Exploitation of Non-Renewable Resources in Protected Areas: Valuation of Protected Areas in Bolivia

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Abstract

It is proposed a method for choosing between two critical options: 1) Petroleum exploitation or the creation of infra-structures versus 2) The conservation of natural protected areas. This conflict arises when short-term profits are confronted with conservation and protection of natural resources for present and future generations. Using methodologies of Nature valuation, Geographic Information Systems and space analysis; the method provides accurate data for decision-takers, allowing possible solutions for this conflict. The research took place in the Biological Corridor Amboró-Madidi in the Eastern Andes hotspot of Bolivia (including natural parks), one of the mega-diverse regions of the World and also one of the most promising Bolivian areas in regard to oil-mining. Our main objective is focused on an inicial economic value (IEV) for the resource "Natural Protected Area" (NPA) in Bolivia. This IEV is useful when an economic compensation is aimed at due to oil-mining priorities. It can also provide valuable criteria for designing environmental policies and taking decisions since it involves information about the economic amount needed as a compensation for all the damage inflicted to a NPA. From an environmental standpoint, the lack of considering economic values has been a limiting factor in the environmental management of protected territories, in this case those exposed to exploitation of a non-renewable resource.

Keywords: conservation, economic valuation, protected areas, oil-mining, corridor Amboró-Madidi.

1. Introduction

When an economic activity involving extraction of non-renewable resources as petroleum exploitation or intensive/extensive mining, or the creation of large infra-structures (bridges, dams, highways) overlaps and therefore threatens protected areas, and then any developing country faces a conflict between two priorities: 1) to generate short-term profits by means of foreign investment as well as expending considerable amounts of money in building productive infra-structures *versus*2) the conservation and protection of natural resources for present and future generations. [1]. For some governments the first is their main priority since large economic benefits are obtained in a relatively short time but without considering the great damages caused by this impact on any environment. The economic and social pressures implied in this choice (exploitation *versus* conservation), that this can also reduce the extension of protected areas or affect them permanently either by pollution or by destruction of natural habitats.

There will always be a global confrontation between intensive/extensive mining and Nature conservation; therefore, a technical procedure that aids to obtain a less harmful damage on the environment is badly needed and in addition it should be capable of providing an economic compensation for the damage caused by productive processes on any ecosystem. The use of natural resources by the Bolivian government is not only limited to a certain extent by the possible damage it may cause, but also due to the lack of any existing compensation used as an exchange for harming a territory.

In this aspect, and from the standpoint of the economic and social sciences involved in this process, a set of solutions can be implemented. These solutions must respond to regulations and in addition, compensation is needed, at least for the values of use and non-use of the environment. At present, many countries have established environmental laws that regulate the technical process of the exploitation of non-renewable resources, leaving political negotiations in charge of economic compensations. The main objective of this paper is to give an initial economic value (IEV) to the resource “Natural Protected Area” (NPA) in Bolivia. This IEV serves as a basis in negotiations involving economic compensations for damages inflicted to Natural Protected Areas (NPAs), and it takes into account the compensation amounts, which in turn are the result of using some methods of economic valuation of Nature, the geographic information systems and space analysis.

2. *Materials and Method*

2.1. General characteristics of the Biological Corridor Amboró-Madidi (CAM)

The Biological Corridor Amboro-Madidi is located on the northeastern slope of the Andes in Bolivia and comprises ca. 139.088 km^2 including the most valuable eco-regions from the point of view of Bolivian biodiversity. It covers 12% of the Bolivian territory and is included in 4 Bolivian departments: La Paz, Cochabamba, Santa Cruz y Beni, 77 municipalities and 12 TCOs[2].Inside this territory, several national parks are outstanding: Amboró, Carrasco, Isiboro-Secure, Pilón Lajas Madidi and the Reserves of Wild life CavernasdelRepechon. Many important species are conserved and protected in these areas following management and scientific-technological programs.

This Corridor lies within the Hotspot Tropical Andes, which in terms of extant species is the richest and most diverse area on Earth since one sixth of all plants are distributed in less than 1 % of our planet land surface [2]. In addition, a biological corridor implies connections between protected areas and high biodiversity zones and therefore aids to reduce the fragmentation of habitats. [3].The highest Bolivian biodiversity is concentrated in this Corridor [4].

2.2. Economic valuation of Bolivian Protected Areas.

The procedure of dynamic optimization was applied as our analytic frame (Equation 1). This procedure takes into account the use and non-use values of protected areas and their sorroundingzones as part of the costs of the exploitation process, allowing to obtain an ecological tax that penalizes the development of economic activities, such as exploitation of physic resources in a NPA or any economic activity that damages the environment inside a NPA or other regions having a high conservation value [5].The social benefits of economic activities in NPA were maximized. Incomes and costs of the exploitation process (petroleum extraction and mining) were compared and updated to current value using a discount value which varies in accordance with the type of activity and the time of valuation [5-7].

$$MAX \cdot J = \int_0^T \{Income - [(Costs\ (production)) + Cost\ (Park)]\} * e^{-rt} dt \quad (1)$$

Environmental repercussions from oil-mining activities were incorporated to this model. Therefore, direct and indirect environmental costs (environmental services provided by plant cover and the disposition to pay for protected areas, respectively) were quantified. These costs were charged to society, due to the economic activities that usually take place in NPAs and other zones that provide environmental services.
Environmental costs were quantified by means of the methodology of economic valuation of environment, that is,

Total economic value (TEV), which distributes the use and non-use values in a natural ecosystem. Use values are classified in direct and indirect use values. Direct use values are those that can be obtained directly from Nature and can be put in the market under their material form. Indirect use values include environmental functions resulting from a natural system and therefore, given their characteristics, they cannot be put in the market or they cannot have a price or a value. Non-use values include existence, altruist and legacy values. All these express the level of utility that a person can have knowing that a certain resource exists and can also be enjoyed by him (or her) and his descendants. There are several methods of economic valuation for determining the values of environmental functions included in a natural ecosystem. These methods have various classification levels according to several standpoints. Hedonic prices and productive functions are used in this paper; they belong to indirect valuation methods and determine the implicit values of a resource by considering the prices of other resources or services related to the resource in question.

The hedonic price model showed the most outstanding characteristics of Bolivian NPAs and allowed their valuation in accordance with international criteria and foreign environmental groups which have expressed their disposition to pay for the conservation of these sites [8]. For visualizing their characteristics, a simulation model of floristic distribution that estimates the number of extant species in a region [9] was used, taking into account the biogeographic characteristics of a territory (Equation 2).

$$\ln(\mathrm{Sf}) = \partial \ln(\text{Área}) + \beta 1(\text{height}) + \beta 2(\text{bioc lim atic}) + \beta 3(\text{coordinate s}) + \gamma \ln(\text{ra inf all}) \quad (2)$$

Where:

Ln (Sf): Number of plant species in a territory.
∂ln(Area): First logarithmic derivative in respect to surface area
β1: Coefficient of the variable height (m a.s.l. of NPAs).
β2: Coefficient of the variable representativity of bioclimatic floors (habitat diversity).
β3: Coefficient of the variable coordinates (South latitude; coordinate means, SERNAP, 2001).
γ ln (rainfall): Coefficient of the variable mean annual rainfall in NPAs (SERNAP, 2001).

Protected areas were considered a market, called donation market, where several economic agents coexist, e.g., donors, fund administrators and representatives of NPAs. This type of market allowed the determination of the hedonic valuation function [p (z)] with the objective of learning how much and how did the money donation changed in accordance with the environmental characteristics of NPAs that are intended to be conserved, once the relations among the various agents involved are established. By observing the behavior of these agents, the balance of money donations to protected areas can be determined.

In the case of fund donors, taken as consumers or clients of the characteristics of NPAs, the level of the characteristics set (z) to be chosen can be determined in order to increase its utility to a maximum [10]. They should decide the amount of their donation in accordance with the conservation level shown by a characteristic of NPAs and by ordinary resources (x) [10]. This maximization of utility should be made by adjusting their budgets and by keeping expenses in ordinary resources and expenses in PA in balance with incomes.

Fund administrators (on behalf of international organizations) make funds (given by donors) flow towards their goal. The donor's disposition to pay is then estimated for a single economic agent adding the individual dispositions to pay of the various economic agents in a direct way, that is, funds given by donors to administrators. In this way, fund administrators will consider these donations as total incomes of their organizations for the conservation, protection and valuation of PAs as long as these last fulfill the expectations of the donors. Administrators should confront operational costs during the development of their operations and also they should confront variable costs in accordance with the characteristics of the NPAs that are to be conserved [C (z)], which could vary in accordance with their locations, geographic characteristics a some other variables.

Representatives of NPAs who offer the characteristics of these natural spaces, negotiate with internacional organizations in order to get the necessary funds for these sites and taking into account their environmental, economic, social and cultural characteristics. All these imply diverse protection and keeping costs and also the cost of opportunity of not taking the area for other uses. A cost function was created, including opportunity and keeping costs (r); unitary costs are the characteristics of NPAs [c(r,z)].

The difference between the availability to pay for the conservation and keeping of environmental characteristics of natural sites and the function of necessary costs for reaching these goals facilitates the obtention of the necessary funds for profits derived from conserving a NPA and considering the loss of opportunity for performing any other activity in the NPA, given its characteristics [$z : \phi(r, z, \prod)$]

After the market balance among donors and Pas negotiators is established, the hedonic valuation function (tangent between the liciting function of an international organization for the conservation of Nature and the offer function of any negotiator from the NPA) is calculated, which includes the marginal valuation of the environmental characteristics of NPAs at their various levels. Costumer's demand is then calculated, i.e., the disposition to pay marginally for an additional unit of the characteristics of the NPA. In order to elaborate the demand curve of the characteristics, the hedonic valuation function is derivated in order to obtain the disposition to pay for an additional unit of the characteristics of a NPA, Which can be represented as:

$$\partial P(z_i)/\partial z_i = W(z_i) \quad (3)$$

Once the disposition to pay is calculated, the money value of a change in the environmental characteristics in question can be determined.

A multiplicative system was used as a structural model for the valuation of Bolivian NPAs. This system includes the characteristics of NPAs as a whole and also their inter-relations. Donations from international organizations are taken into account as a variable that can be explained by the particular characteristics of a NPA. From the regression executed and the methodology explained above, the disposition to pay for certain characteristics is obtained. The regression was estimated in natural logarithms using variables such as fund donations from international organizations in American dollars (Lpre), the area of every NPA in hectares (Lar), area of every NPA to the square (Lar^2), total population living inside the NPA and also in its surroundings (Lpoptot), number of plant species found in the NPA (Lflora), and the number of animal species found in the NPA (Lfauna).

The data base from the financial report of the Bolivian NPA System (1996-2004) was used, with references to the funding for every NPA and including source of origin and final place of execution. Also, thebiogeographicdescriptionforevery NPA in thebook "Información Técnica del Sistema Nacional de Áreas Protegidas de Bolivia" (ed. SERNAP 2001) was taken into account as well as the updated websites of SERNAP and the "Fundación Amigos de la Naturaleza".

Production functions were another method employed for evaluating indirect services obtained from natural areas. This method revealed, in an indirect way, the money amount that society would be willing to pay in order to conserve the actual Bolivian plant cover using the value of marginal productivity of Pas in accordance with their types of plant cover [11] and as sources of environmental services for the budget of Bolivian economy

The aggregated production function type Solow-Stiglitz was used:

$$\text{Value of marginal productivity} = GDP * \frac{\partial f(N, P, K, T_i, L)}{\partial T_{anp}} \quad (4)$$

Where:
N: Environmental quality
P: Technological progress
K: Capital made by man (or artificial)
T: Natural incomes, i.e., the environment as a whole (forests, grasslands, agricultural land)
L: Labour workers

Synce our analysis took place in NPAs that do not belong to priority conservation areas, we may follow Samuelson's rule, which works on public resources from an economic perspective. Society should offer, in optimal form, a public resource until the addition of marginal values of substitution between public welfare and the rest of the private resources of society are equal to the marginal value of transformation of the production (by society) of this public resource [12].

In estimating the model, the databases of the World Development Indicator and FAO-Stat (version 2005 including from 1986 to 2002) were used as complements. 1986 was chosen as starting year of the model, due to a significant structural change in the Bolivian economy in 1985; if this last had been chosen as initial, it would have introduced alterations in the regression.

Also, an estimate of square minimum (OLS) was made in two stages. During the first, an error correction model of the long-term production function was developed. During the second, the information obtained from the regression was used in a method of square minimums in 2 stages allowing the correction of multicolinearity problems in the equation system and the development of a consistent estimate that offers an inference. This last employs the inter-relations of the equation system.

Last, the elasticity of every plant cover was calculated, using the multiplication of all partial elasticities. Using the concept of marginal product value, the mean value that society gets from every type of plant cover was elucidated. In this way, the amount that society gets from having current plant covers was revealed indirectly. This amount can be equaled in accordance with Samuelson's to the disposition to pay for keeping the current state of conservation of plant cover.

3. Results and Discussion

3.1. A model of distribution for the flora of NPAs in Bolivia

The process of simulation of flora distribution in the NPAs showed the species richness that is supposed to exist in a NPA lacking human activity (Table 1). The use of floristic diversity was based upon two main reasons. The first was the close relation between flora and geographic characteristics. The second was the lesser variability in time that allows transversal cuts without the need of controlling the temporal factor. The samplings of the SERNAP offer information about 17 out of the 21 Bolivian parks.

There are ca. 18000 vascular plants species in Bolivia, which is among the 12 most biodiversity-rich countries in the World. According to Bolivian law and demands of financers, a NPA should have a nuclear (core) area lacking human activity.

Our model proved that a relation between geographic characteristics and species biodiversity exists in any territory. This model offers tha possibility of analyzing these factors in a joint way in order to observe the synergies that arise from their inter-relations. It also reinforces the following hypothesis: the bigger the habitat diversity, the bigger the number of species. The underlying factor is altitude, which limits species diversity in any territory. Plant species reached ca. 5000 taxa. This model is convenient because it can be used as a theoretical base for the development of conservation policies in species-rich areas [15].

3.1. Hedonic prices. Valuation of characteristics

The hedonic price theory started with Griliches (1961), Lancanster (1966) and Rosen (1974). They claimed that goods sets having a single price are frequently found in real markets; however, the price of an element in those goods is what really matters, i.e., to infer the value assigned to the characteristics of a resource from its price [8].

The construction of a donation market allowed the simulation of the behavior of various economic agents interacting on the conservation of a NPA. This type of market is not competitive and it has a disposition to pay for goods that have no physical use. In this case, goods have an implicit utility, since knowing that they really exist is an incentive for paying a representative of a NPA or a fund administrator in order to guarantee their long-term existence. In this way, we can learn how fund donations change, based upon the characteristics of the NPA that we intend to conserve.

In the case of donors, the selection point lies where the licitation function is tangencial to the hedonic function (Fig. 1), rendering the maximal utility with the basic request of having clients willing to pay a sum (θ) that should be equal to the money income [p(z)].

The two licitation functions, applied in two different levels of utility, show how much would a client pay (donations) in accordance with the different levels of conservation of the characteristics found in NPAs (z). The higher the levels of money value of z, the higher the profits. Also, clients are confronted with the problem of determining what z levels they should choose in order to increase utility. As said above, the selection point is to be found where the licitation function becomes tangencial to the hedonic function, rendering the maximal utility and based upon the following rule: the money that a client is willing to pay (θ) should be equal to the money income [p(z)].

In the case of fund administrators, an aggregation function of licitation is proposed, taking into account the characteristics of NPAs, their conservation costs and the benefits for the fund administrator (figure 2).

The aggregated function of licitation, when it becomes tangencial to the hedonic valuation function[p(z)] renders the maximal profits for the administrators, but with the premise that the amount they are willing to pay [$\psi(z)$] should be equal to the marginal cost involved in conserving the characteristics of NPAs and fulfill the goal of conserving them.

The two licitation functions for different profit levels show how much an administrator would be willing to offer for the different conservation levels of the characteristics of NPA (z). The lesser the money valuation levels of z, the bigger the profits. The offer function of offerersor representatives of NPAs becomes tangencial to the hedonic valuation function [p(z)], reaching the negotiation range. We can use the point in which the negotiator would be willing to agree on a cost level (r), on certain characteristics of a NPA (z) and on a profit $\prod_{anp}$ (Fig. 3).

In this way, a market balance can be established (fig. 4)in which the hedonic valuation function [p(z)] is the tangent between the licitation function of an international organization for the conservation of Nature and the offer function of some NPA negotiator. The set of possible tangents between these two functions represents the fact that slopes in both functions are equal inter se and at the same time they are equal to the money valuation.

The estimates of flora distribution models using hedonic prices show the non-linear carácter of the variable area indicating that, the bigger the size, the bigger the disposition to pay until a limit is reached; in addition, the greater the biodiversity, including reported species of flora and fauna, the greater the disposition to pay; also, the largest the population incide a NPA, the largest the value of the site.

The values of existence in Bolivian NPAs/hectare (Tab.3and Fig. 5) revealed a problem of statistical significance in the variables flora and fauna. This could be due to the existence of colinearity between these two variables. This colinearity was established when estimates were made without taking into account one of two variables. Estimates gave the same coefficient and the statistical significance of both variables kept itself within the limits of standard acceptance. Since our goal was the valuation of the main characteristics of NPAs made by international organizations, the colinearity of data was assumed. The value of existence/ha in a NPA ranged between 74 and 469 American dollars, according to geographic characteristics, surface, flora, fauna and human population in every area.

International organizations donate funds for Nature conservation in order to preserve natural ecosystems in NPAs for present and future generations, that is, they finance the value of existence of NPAs through their disposition to pay (DP). This means that their disposition to pay has a close relation with relevant characteristics found in NPAs. The disposition to pay of international organizations can be determined by measuring the effect that an impact, caused by the creation of infrastructures or by oil exploration techniques, among several activities, can have on a single hectare in a NPA. If an impact on natural resources takes place in a NPA or a decrease in its area, the value of that particular site will also decrease. This leads to a conclusion: a decrease in natural values of a park involves a remarkable decrease in the money incomes that international organizations could contribute as fund donors.

Production functions, revealing the disposition to pay of human society in order to conserve the extant soil covers in Bolivia.The amount that society gets from having present Bolivian soil covers is obtained in an indirect way and this amount can be homologyzed, according to Samuelson's equation, to the disposition to pay for conserving the current conservation state of plant cover. Mean elasticity/plant cover type is shown in Table. 4

It should be emphasized that, the payment for the conservation of forest cover and the payment for the conservation of other cover types, mostly scrubs and thickets, are among these dispositions to pay (Tab. 5). These two cover types with their ecosystems are the main providers of many environmental services still not acknowledged by human society **[16].**The recognition of this type of money income will give, either for society, administrators or forest owners, the opportunity to re-valuate the actions of conservation and management of these ecosystems.

Transference of financial resources to the preservation and improvement of natural ecosystems is common nowadays. Several economic studies have assessed this subject and the term “payment for environmental services” (PES) has arisen from these studies. PES is defined as the amount of money donated by various agents, who use a natural resource or use the environmental functions of an ecosystem, to persons who keep, conserve or own the management of these natural ecosystems. In several Central American countries, this type of market has become effective, working through the articulation of economic instruments and mechanisms (environmental taxes, concesions, fees, among others) that intend to grant the transference of these money flows to the conservation of the environment. Up to now, the functions and services provided by natural ecosystems have confronted changes in plant cover due to the establishment of productive infrastructures in a territory. Since society is also affected by this situation.It must have the possibility to impose an “environmental cost” to these damaging activities and this environmental cost should be an equivalent of the money amount that society receives from the benefits of natural ecosystemservices.

In this case, the quantification of PES establishes, in an indirect form, the amount that society gets from keeping these services. Doing this, by using large economic aggregates, allows the replication of the system employed in several economies and aggregation scales.

To start with the influence that several geographic factors have on the flora diversity of a region is a first step towards the establishment of policies for its management. These policies should find the inter-relations between the conditioning factors of a flora and human activities.

3.4. Application of Compensation Funds for Oil Companies.

Our research reached an initial value for negotiation that offers the possibility of compensation processes in NPAs exponed to high impact activities. The process of application of these compensation amounts was performed in tour NPAs under high impact (tabla 6), with a discount value of 3 % and a period of 100 years. As a result, compensation amounts have been obtained which are quite larger than those established in previous negotiations when the Bolivian state confronted such projects. Most negotiations have been discussed politically and the influences of technical factors have had no repercussion in their results. However, this method does not put any emphasis on the form under which it should be applied. For implementing the method, we recommend to start with a political analysis in which the state and private sectors should participate.

Concerning the selection of a discount value, it is better to have similar or lesser values than those shown in this paper for State valuation processes. This might modify to a great extent the actions of enterprises, favoring productive processes involving fewer damages to the environment. As compensation values increase, enterprises are encouraged to modify their productive processes by introducing technologies less aggressive to the environment.

In the field of oil exploitation, it is necessary toimpose a higher impositive charge, not only because of their meager contribution to the Bolivian funds [17-18] but also because it is rational that enterprises give an economic compensation for the environmental damages they have caused [19]

Since there still are conflicts concerning the types of activities allowed in NPAs, as well as the money amount for compensation that enterprises should pay, a better coordination in legal systems should be a priority in dealing with the confrontation between environment conservation and energy production. These legal systems should include specific rules or laws about the methodology for estimating economic compensation in case of damages in NPAs during the development of activities of oil enterprises.

Therefore, the establishment of taxes on oil exploitation and use of space within a NPA can be a complement to the goals of environmental laws, i.e., “to allow exploitation of a resource but without any damage to the environment”. Taxes then become an additional instrument of laws.

4. Conclusions

This research proposes a model for incorporating environmental costs to oil enterprise activities with a high environmental impact (creation of infrastructures, dam systemsand oilpipes). The geographic characteristics of Bolivia affecting flora distribution and type of plant cover influence of biodiversity, territorial extension and human communities are very important factors when considering valuation processes performed by international organizations. The environmental services provided by plant cover in a territory have aided to establish existence values in NPAs, which is a contribution to the balance of ecological systems and productive processes in human society. Biogeographic characteristics play a primary role in the establishment of economic compensation amounts when environmental damages are involved. This requires thorough scrutiny for every endangered site. The determination of proper discount values in order to establish economic compensation amounts are determinant when future conservation policies in biodiversity-rich habitats are needed.

References

Olivera-Villarroel S. M. (2005), the economic value of the protected natural areas, Economy Informs 333 72-86.

USAID (2007), Corridor of Conservation Amboró-Madidi (CAM), available at: http: www.conservation.org.bo/.../Final Inform_PCP.p

CalderónA. L. (2004), Protection and Conservationareas of BiocorredorAmboró-Madidi (CAM), Santa Cruz: Fundación Amigos de la Naturaleza, available at: http: www.sernanp.gob.pe/sernap/.../biocorredores.pdf

BarthlottandCalderón A. (2004), Protection areas and of conservation of the biocorredorAmboró-Madidi

Pindyck R. S., (1978) the optimal exploration and production of nonrenewable resources, Journal of Political Economy 86 (5) 841-857.

Edwards G. (2000), Introduction of the Analysis of Dynamic Systems, Catholic University of Chile,

Chiang A. C. (1992), “Elements of dynamic optimization”, McGraw-Hill, Singapur

Palmquist R. (1991), Hedonic methods, in: Braden J. and C. Kolstadt (Eds.), Measuring the Demand for Environmental Quality, Elsevier, and North Holland.

Anderson R.P., D. Lew and A.T. Peterson (2003), Evaluating predictive models of species distributions.Criteria for selecting optimal models, Ecological Modeling,16, 211-232.

Rosen S. (1974), Hedonic prices and implicit markets: Product differentiation in pure competition, Journal of Political Economy, 82 34-55.

Azqueta D. (1994), Economic valuation of the environmental quality, Mc Graw-Hill (Ed.), Madrid, FA

Sterner T. (2003), Policy Instruments for Environmental and Natural Resource Management: Resources For The Future Press, Washingofn, D.C,

Bueno Bousquets J.L (2005), The biogeographic work of Alfred Russel Wallace, Part ll- El modeloextensionista y la inflexión al permanentismo, in: Bousquets J.L. (Ed), Biogeographics regionalization in Iberoamerica and similar ofpics, 19 (26), National Auofnomous University, México D.F.

Arellano L and, G. Halffter(2003), Gamma diversity derived from and a determinant of alpha diversity and beta diversity and analysis of three tropical landscapes, Mexican Act Zoological,90 27-76.

Arita H. and P. Rodríguez (1999), Applications of the Geographical Ecology and the Macroecology, Circular Guanabios, available at: http-//www.guanabios.org/circular/1-10/1-10-36.html.

National Service of Protected Areas and Plural (2001), National System of Protected Areas of Bolivia, National Service of Protected Areas, La Paz, Bolivia

Villegas C. (2006), Exploitation of the Hidrocarburíferos Resources in Bolivia. Problems and Perspectives, FOBOMADE-Bolivian Forum on Environment and development, Geopolitical, 133-140

Olivera-VillarroelS.M. and F.P. Grigoriu (2005), A Model of Dynamic Optimization of Exploitation of Petroleum for the Bolivian Economy, UMSS-IESE, 15 (26) 75-96

Presidency of the Republic of Bolivia (2005), Law of Hydrocarbons-Law 3085, Official Gazette,

Annex I: **Table 1: Simulation of the flora distribution model in Bolivian PROTECTED AREA s**

PROTECTED AREA	Spfo.	Sha.	R.	Coom.	AMax.	AMin.	PM.	Spfe.
Sajama	154	112,416	2	1992	6542	4000	335	42
Apolobamba	807	466,525	4	1641	6200	800	1100	1473
Madidi	5000	1,867,810	4	1536	6000	200	2850	4899
Eduardo Avaroa	102	687,874	2	2471	6000	4200	100	37
Cotapata	820	61,257	4	1783	5900	1000	2000	523
Carrasco	614	687,186	3	1917	4700	300	5000	473
Tunari	.	326,367	2	1897	4400	2200	900	288
Tariquia	808	247,435	3	2426	3400	900	1950	271
Amboro	2961	669,419	3	1842	3300	300	2250	2770
Isiboro Secure	402	1,256,598	2	1773	3000	180	2700	800
Pilon Lajas	624	398,451	1	1643	2000	300	2250	256
San Matias	874	2,886,350	1	1936	1210	108	1469	584
Aguarague	.	111,076	1	2365	1900	750	925	110
Noel Kempff Mercado	2614	1,602,359	1	1575	750	200	848	2573
Kaa-iya del Gran Chaco	880	3,426,545	1	2097	400	200	700	846
Manuripi		760,501	1	1309	269	128	2158	10606
E. B. del Beni	815	134,118	1	1613	250	210	2200	1168
Elaborated by authors of this paper using model data and SERNAP								

Abbreviations: Spfo. (Plant species reported), Sha. (Surface in hectares), R. (Representativity), Coom.(Mean coordinates), AMax. (Maximal altitude), AMin. (Minimal altitude), PM. (Mean rainfall), Spfe. (Plant species estimate).

n order 1, no constant
Samples: 1996 – 2004. Z statistics ( ) y P>|z| [ ]
Log natural area
1.21611
(5.75)
[0.000]
Log natural area Square
-0.0474
(-5.10)
[0.000]
Log natural population in the area
0.18216
(1.82)
[0.068]
Log natural species flora
0.15451
(1.17)
[0.243]
Log natural species fauna
0.16367
(1.35)
[0.178]
Number of observations = 112
Number of groups in sample = 16
Panel: heterocedastic (Not balanced)
Structure of autocorrelation: AR(1)
R-square = 0.9920
chi2(5) = 15300.72
Prob> chi2 = 0.0000

Table 3: Value of Existence of Bolivian NPAs/ha in American dollars

Protected Area	Value of Existence	Area (ha)	Species Fauna	Species flora	Human pop.
Madidi	469	1,867,810	1833	5000	13013
Amboro	376	669,419	1236	2961	18419
Tunari	374	326,367	197	288	1080000
Gran Chaco	348	3,426,545	514	880	25070
San Matias	340	2,886,350	215	874	54592
Isiboro Secure	321	1,256,598	714	402	45563
Manuripi	288	760,501	963	5000	1664
Tariquia	273	247,435	806	808	27284
Pilon Lajas	272	398,451	1448	624	14134
Noel K. Mercado	252	1,602,359	1098	2614	1400
E. B. del Beni	252	134,118	852	815	25051
Carrasco	247	687,186	382	614	19800
Apolobamba	230	466,525	275	807	18500
Cotapata	172	61,257	204	820	18260
Otuquis	159	1,006,620	114	104	17894
Sajama	108	112,416	108	154	7000
Eduardo Avaroa	104	687,874	96	102	2662
El Palmar	103	59,972	196	270	3053
OfroOfro	91	16,687	49	329	10700
Cordillera de Sama	82	105,021	197	67	4000
Aguarague	74	111,076	215	10	10221

Table 4. Mean elasticity/plant cover type

Total area	Arable	Permanent pastures	Forests	Other types of cover	Adjustment/pop.
0.14937	0.01743	0.05128	0.05133	0.00814	0.0212

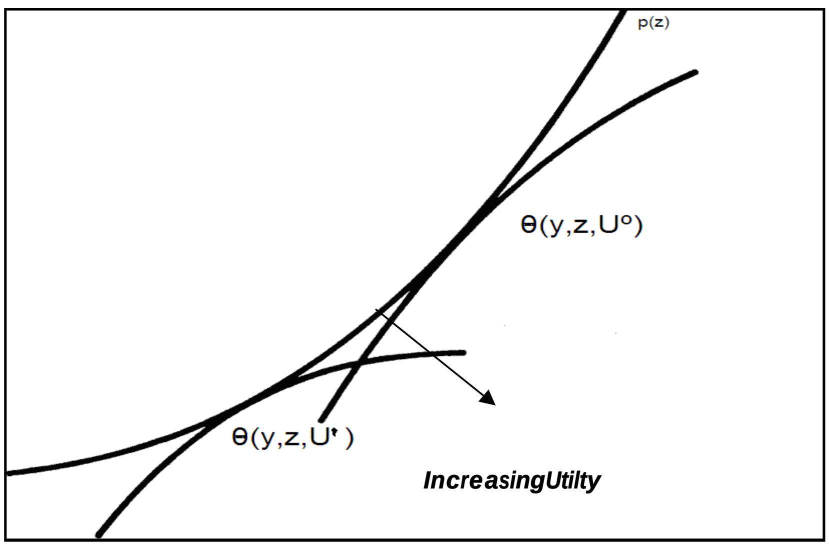
Table.5. Mean income/plant cover type for the Bolivian economy in American dollars.

Year	Global	Arable	Permanent pastures	Forest	Other Types of Covering
1986	5.45	31.31	6.15	3.58	5.61
1987	5.99	34.02	6.76	3.95	6.02
1988	6.33	35.61	7.14	4.19	6.22
1989	6.50	36.20	7.28	4.31	6.44
1990	6.70	37.62	7.52	4.46	6.46
1991	7.36	40.56	8.18	4.91	7.31
1992	7.77	42.19	8.64	5.21	7.42
1993	7.90	42.03	8.69	5.32	7.68
1994	8.24	41.43	9.07	5.57	7.84
1995	9.25	43.91	10.18	6.29	8.64
1996	10.19	46.82	11.21	6.96	9.24
1997	10.92	45.58	12.01	7.50	9.91
1998	11.71	47.21	12.88	8.08	10.37
1999	11.41	45.58	12.56	7.92	9.76
2000	11.56	46.70	12.72	8.06	9.46
2001	11.05	45.09	12.16	7.74	8.69
2002	10.75	43.77	11.82	7.55	8.27
Source: authors of this paper based on the calculation of the value of marginal product					

Tab.6. Application of compensation amounts for environmental damages in Bolivian NPAs in American dollars

PROTECTED AREA	Surface (ha)	Area affected by infrastructures (ha)		Value of Existence ha.	Value of Indirect Use	Precio Sombra del para el Sector Hidrocarburos	Value of total compensation of PAS	Valuelor Anual Reducido por Infraestructura	Net present value; years 100; discount value 3%	Recognized value
Carrasco	687,186	6,144	Oil area	273	8	258	539	3,310,646	-$107,751,200	$0
San Matías	2,886,350	210	gasoduct	340	8	775	1123	235,926	-$7,678,670	No data
Gran Chaco	3,426,545	600	gasoduct	374	8	771	1153	691,534	-$22,507,290	$3,000,000
Tariquia	247,435	3,400	dam	252	8		260	885,269	-$28,812,758	$500,000

$p(z),\theta$

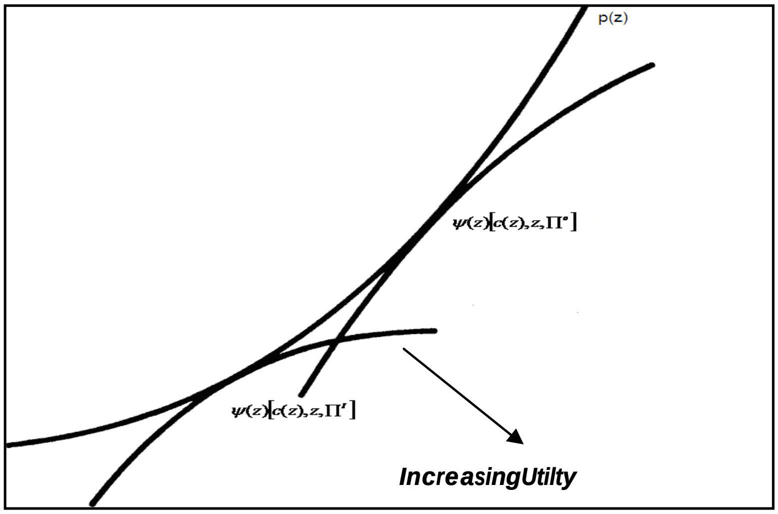


$\theta(y,z,\hat{U})$

Characteristics of the NPA, z

Fig.1. Selection of a client; modified from Rosen (1974)

$p(z),\psi$

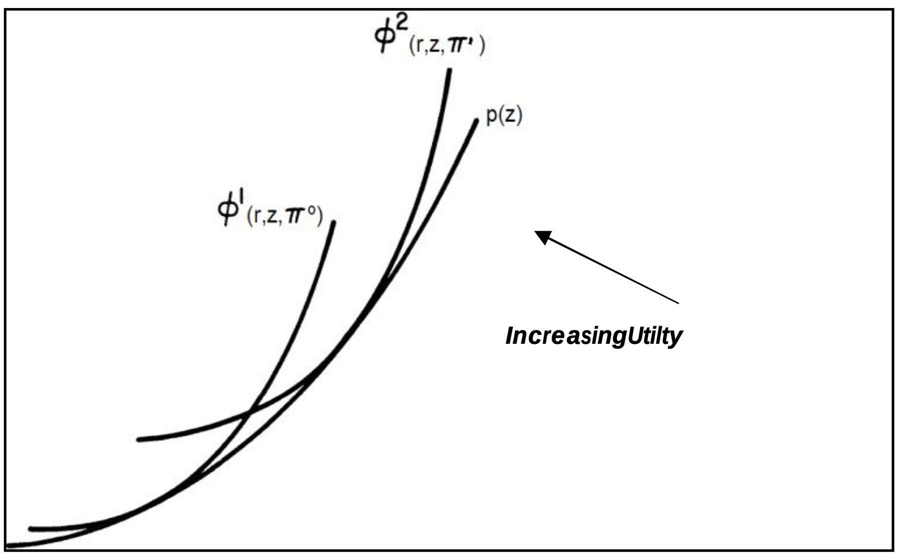


$\psi(z)[c(z),z,\prod_{OI}]$

Characteristics of NPA, z

Fig. 2. Selection of a fund administrator

P(z), ϕ



$\phi(r,z,\prod_{anp})$

Characteristics of NPA, z

Fig. 3. Selection of an offerer

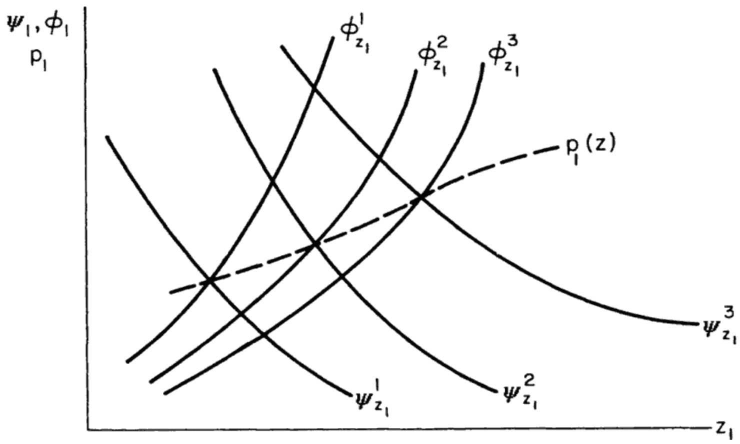


Fig. 4: Graphic representation of hedonic market balance adjusted to NPAs.

Values of existence in flora and fauna

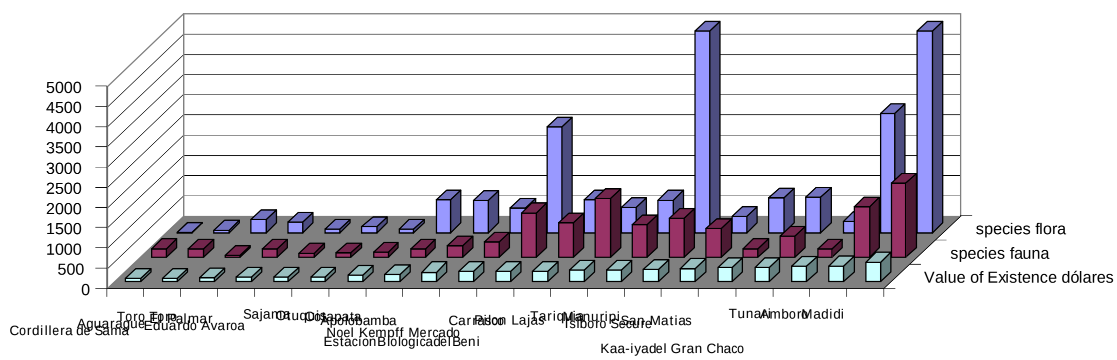


Fig. 5. Graphic representation of values of existence in flora and fauna