Ecological-Economic Valuation of Prestigious Species in Case of Human-Wildlife Conflicts: The Elephant Example

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Abstract

In land use conflicts between humans and nature, in particular in case of prestigious species (here elephants as example), typically valuation is done from a human perspective, i.e. anthropocentric. It is based on human utility, willingness to pay, etc.; yet in a biased way, because a user states preferences without knowing "costs of nature" in provision. I.e. we have no mean of recognizing nature wealth per se. We depart and include an energy loss minimization as a complementary optimization of nature (as surrogate for wealth) and aim at detection of "values" from behaviour. The value detection is combined with a system analysis on human-animal-energy-acquisition and the corresponding – conflict is spelt out. In a system analysis on conflict we equate biomass (energy) demand of humans with that of species at highest trophic level (as said elephants). Then adjustments look at reaching equilibrium; this is made letting shadow prices change. In this regard we emulate a joint welfare analysis as if demands equate; we assume two different demand functions for land: humans and animals. The allocation is considered "optimal" and delivers us "values".

Keywords: land use conflict, valuation, optimal allocation, shadow prices

JEL Codes: D6, Q24, Q34, Q57

1 Introduction

Land use conflicts between humans and nature are omnipresent. A matter of urgent analysis is the ecological economic evaluation of species in terms of their importance for conservation and securing of survival of endangered species under economic threats (Daily et al. 2011). Such aim is important because it seems that only joint values (preferably monetary once, but including nature functions which are linked to ecological scarcity) make humans recognize and acknowledge nature (Everard, 2009). However, the current valuation theory prefers monetary valuation isolated from knowledge about nature (at least most citizens just express preferences). Monetary valuation is conducted from the point of view of consumer preference (i.e. one “exceptional” species, homo, “evaluates” based on utility derived from nature). In principle it means nature values compete with other values in consumption, and deprivation of nature and loss of lands on which nature has no property rights are the consequences. This happens since species compete with other use of land for human purpose (food, fibre, etc.) on basis of a “valuation” by a single user. (It is me determining the land price of my neighbour).

Then the basis for valuation is utility theory. Utility is a measure which is given by willingness to pay or acceptance of variations in provision of goods and services, also nature; for instance food hunted or species appearance are linked to land. But revelation works without real cost (actually the provider has no property right on land as “he” is not part of a social system). Land use conflicts prevail yet. In the past, humans were capable to transfer biomass only to a certain extent into utility by hunting, gathering or farming. Today, since humans have strong access to fossil energy, their acquisition potential is bigger. As a result humans have stretched out land occupation and energy acquisition by both, per capita consumption and population density per unit of land.

Note occupation of land and evaluation of food and species also depend on income levels. Especially income levels have risen tremendously, equally due to the use of fossils, and nature is more and more restricted. Perhaps current willingness to pay for food and land is overestimated to due to high income. Also, it can be stated that consumption has sharply deviated from a concept of basic needs. A conflict between preference as utility or fun and need for survival in determining land use has emerged. A question is how can humans in their evaluation of nature (confronted, for example with elephants in land conflicts) be restricted (in consumption) to assess needs rather than preferences.

In less pronounced ways, perhaps one can one suggest concessions between utility and need as alternative to pure utility? Working in ecological economics with “needs/energy” instead of “preferences/utility” poses a challenge to economists to find a new balance between preferences and needs. Working with utility should be modified. A next question is how can we model a market of needs rather than market based on preferences? The distinction between needs and preferences (Rauschmayer et al., 2011) is a building bloc for sustainability. The plea is that humans should look at needs instead of preference as in current economics. Then a question is: can we compare needs and utility and in what “currency”. If we want, for example, recognizing needs of species like lions or elephants (for survival), their land needs must be detected and compared with human needs (for food, etc. for land): what could be the equilibrium?

There is an immanent request to model the valuation of resource in a conflict of human and specie’s needs as equilibrium and at the level finding compromises; for instance, to look at the issue in terms of revealed “land scarcity”. Also note values should be objective rather than subjective; this requires finding the equilibrium between supply and demand. Then, if one speaks of equilibrium in demand for different land uses (human vs. nature), we may see best use strategies. Since the supply of land is fixed, valuation and allocation are to be combined in finding equilibriums. In principle the idea of the paper is: valuation can happen like on land markets; humans and other species compete for land and hereby we simulate prices (marginal values). The normative aspect of valuation (pricing of resource) is that, in equilibrium (as game), there is yet allocation of resources which increase social welfare of co-operating units.

So what is a social optimum in a community of humans and species? What is a corresponding marginal value in land use for nature (conservation area or nature parks)? And humans should pay for fields (for food production) in what?
In the following analysis the aim is to explore the condition for equilibria between prestigious species (for example elephants) and humans. The outline is as follows: First, the topic is elaborated and we argue why there is a calling for such type of valuation. Second, a model is deployed which contains both, preference and basic need maximization. Humans are modelled as hybrid having utility and "needs" and elephants as having needs for fodder. Hereby we determine population sizes. Third, the interaction is portrayed as exchange of labour and water for elephants, which need water points and humans who want fields (land) needed for food and fibre and hunt. Fourth, our evaluation is obtained by shadow prices which constraint populations of humans and elephants interactively. It is the objective of the paper to base the concept of valuation on equal recognition of needs and construct links between needs and preferences.

2 Background and approach

Normally the construction of transactions would imply a discussion on rights and institutional settings (Hanna et al. 1996). We avoid that and immediate think about land markets. Actually there is a parallel of our approach in, what is the determination of land price and how it is achieved by equilibria? As for a comparison equating shadow prices of land, normally by farmers, in a stylized land market, ends in finding a joint optimum. In this regard, we seek to equate shadow prices of need functions. So we start with a constrained maximization and then apply a mechanism which equates constraints. For the analogy to land markets: on land markets land constrained farmers compete and the prices is the outcome of a game. Competition equates marginal profit functions. Hence we have to derive marginal interests (here not profits instead marginal "need" functions, which are most relevant in seeking an ecological-economic optimum. In our model we specifically aim at outlining marginal need functions as derived from artificial goals (objectives), which have to be derived as stated objectives. Stated objectives can be minimization of losses in energy conversion from lower trophic levels to higher levels (Tshirrhart, 2007). The innovation is that we combine utility maximization with energy loss minimization. Also we aim at specifying the (i) population size, (ii) energy in food and (iii) labour economy as constraints which give income of humans. The human side is specified as consumers receiving food from nature priced as food scarcity which is the result of demand given supply. These prices shall be linked to the competition for land between humans and animals. Then for the side of ecosystem, which is represented by elephants, energy loss minimization is suggested as objective function. The elephants dwell on plants which are established as land request and plants are eaten and as emulated in a forage supply of a food web. The matching energy exchange emerges as value. On the interaction between humans and nature (elephants) as well as the suggested equilibrium, we work with a traditional adjustment of shadow prices as based on surplus/deficits. Note that a shadow price for humans is different from those of nature and they may not equate. Rather our mechanism of adjustment is taken as energy related shadow price and species concordance. Species concordance is specified as co-incidence of “wished” and provided species levels from lower trophic levels to upper. In modelling we make a reference to a sub-model of human capacities to support the prestigious animal.

Finally, the equilibrium serves to derive optimality including fixed variables. Then, we work with iteration: (1) for humans, elephants are fixed which provide hunting meat; (2) for elephants, humans are fixed who can provide water. A fixed variable approach in this regard means, citizens (humans) cannot decide on the variable “nature (elephants) because it is given exogenously (in our case by equilibria) to them. Populations are becoming endogenous to the system, later. In this case shadow prices are changing for given constraints (as shortfall of the paper: no mechanism is explicitly modelled). From the point of view of valuation it means that by adjusting constraints we obtain the equilibrium, i.e. automatically, and also the shadow prices are adjusting which will be shown.

3 Modelling humans

Our modelling is a description of the consumption side of humans. We start with a traditional utility maximization approach which is used in neoclassical theory for deriving demand functions and specifying behaviour. The approach is basically descriptive, i.e. neutral in the design of preferences, does not care about energy, and leaves the issue of normative prescription to revealed preferences as concept. However, it includes already section on a minimum consumption being part of a norm of survival. Utility is measured with a Klein-Rubin-utility function on the side of humans (Varian, 1978):

$$U = E^{\beta_2} X^{\beta_1} \prod_{i=3}^{n-1} (q_i - x_i)^{\beta_i} l^{-\beta_n} \qquad (1)$$

where: E : elephant
X : population
q : consumer goods
l : disutility from labouring

In function (1) we distinguish between per capita consumption and population. The approach is an extension of the usual multiplication of per capita and population preference (Daily et al, 1994). Since adding of consumption coefficients gives 1, it is a different way of weighting priorities. Weights express preferences (in an index it means that weights are summarized as welfare). However, in the specification we leave the preference open to an empirical analysis.

Moreover, since it is difficult to specify the preference of humans and their nutrition situation simultaneously, it seems that science is vague in population size determination. The implication is that one must extend the approach to an individual and a community approach. Yet the assumption remains the same that a “content free” utility maximization is delivering “demands”, but here things are different. We need to reveal preferences for human population. It may allow us to infer the coefficients from econometric analysis. For this we include additionally the number of elephants as part of the reference function. The number of elephants is assumed to be fixed for consumers, but it is part of preference and we add a negative preference for labouring.

Importantly the preference function works with minimum consumption. I.e. real preferences start above a level of minimum or basic need consumption of food. Note we did not include a minimum for elephants and labour. The next issue is how to deal with prices (costs) of population and elephants. Again /and additionally we have to find a position above benefits; also from labour as opposed to costs which are represented by negative preference for working.

- excursion: For getting preference for elephants, it might be possible to establish a unit cost on basis of damage in the food production system, which reveals costs, and we could make a regression on effects taking the utility function. Labour costs are perhaps easier to find because the simple model used here is corresponding to a general farm household model in which utility is put above farm income (Sadoulet et al., 1998). However, it is difficult to infer from observation to preference of non-market goods (elephants), it might work. End -

Furthermore the assumption is that income is generated by labouring which depends on the prevailing wage rate. This assumption provides constraint (2):

$$w \; l \;\; = \sum_{i=1} p_i \, q_i \; + x_{w,e} \, p_{w,e} \qquad (2)$$

where: w: wage
x_w : water

Additionally we include a water quantity and price which is discussed below. The question (i.e. the one about embedding of the constraint in further physical conditions) is how much time and labour is devoted to support elephants. This issue is manifested in a second constraint (3). And this second constraint is the land constraint. For simplicity land is parted for human use and elephants.

$$a^t \; = a^h + a^e \qquad (3)$$

where: a: areas

For the moment the number of humans and elephants is linked to these constraints linearly, which will be discussed later in detail. There is a necessity for re-adjusting energy intake, if preferences are more relevant than basic needs.

$$0 = \sum m_i x_i + e_h \tag{4}$$

Where e_h is the energy made available and the m's give the usable energy use per person in the diet: The situation which is modelled refers to a situation of energy surplus for humans. This aspect enables us to classify the preference according the energy contents. However we have to find the value of the constraint (4). The value of the constraint is derived from in a micro-optimization given as utility dependent on energy availability for consumption. Such optimization delivers shadow prices! In scenarios, finally, we assume that preferences determine energy wasting; wasting is possible until a limit. Later we discuss a change in limits and assumption. Here we start with optimization of:

$$U = E^{\beta_2} X^{\beta_1} \prod_{i=3}^{n-1} (q_i - x_i)^{\beta_i} l^{-\beta_n} - \lambda_y [y - \sum p_i q_i] + \lambda_e [\sum m_i x_i + e_h]$$

It means taking derivatives, general terms for commodity i we receive are (6):

$$\partial U / \partial q_i = \beta_j (q_j - x_j)^{\beta_i - 1} E^{\beta_2} X^{\beta_1} \prod_{i \neq j}^{n-1} (q_i - x_i)^{\beta_i} l^{-\beta_n} - \lambda_y p_j - \lambda_e m_j = 0 \tag{6}$$

This is the same as if we substitute 1 for the indexed utility (see Varian, 1978)

$$\partial U / \partial q_i = \beta_j (q_j - x_j)^{-1} U - \lambda_y p_j - \lambda_e m_j = 0 \tag{7}$$

A major problem is now, that the results depend on a utility level U and 2 shadow prices. For this we have to eliminate them. Actually the 2 shadow prices have to be determined simultaneously. The problem emerging with the utility can be avoided using a logarithmic version of Klein Rubin which results in

$$\partial U / \partial q_i = \beta_j (q_j - x_j)^{-1} - \lambda_y p_j - \lambda_e m_j = 0 \qquad (8)$$

This optimization can be supplemented with a minimization of energy losses. The way to do it is, in principle, to minimize using the same function as constraint, but now energy lost is minimized given consumption levels. (9)

$$e_h = \sum m_i (x_i - q_i)] + \lambda_u [U_n - E^{\beta_2} X^{\beta_1} \prod_{i=3}^{n-1} (c_i - q_i)^{-\beta_i} l^{-\beta_n}] - \lambda_y [y - \sum p_i q_i]$$

The minimization (10) is energy oriented; it has a certain utility limit which has to be obtained from consumption. In such case optimization provides us a description of optimality such as where we again argue with the logarithm:

$$m_i - \lambda_u \beta_j (c_i - q_i)^{-1} - \lambda_y p_i = 0 \qquad (10)$$

Mathematically by dividing the equation by λ_u we get

$$1/\lambda_u m_i - \beta_j (c_i - q_i)^{-1} - \lambda_y / \lambda_u p_i = 0 \qquad (10')$$

And a transformation of the shadow prices gives:

$$\lambda_u' m_i - \beta_j (c_i - q_i)^{-1} U_n - \lambda_y' p_i = 0 \qquad (10'')$$

Hereby a similar structure prevails as in the case of utility maximization. But, arguments are different: energy units instead of prices. Taking once more the summing up 2 equations exist which allow us to calculate the shadow prices.

$$1 - \lambda_y \sum p_j [q_j - x_j] - \lambda_e \sum m_j [q_j - x_j] = 0 \qquad (8'')$$

$$1 - \lambda_y \sum p_j [c_j - q_j] - \lambda_e \sum m_j [c_j - q_j] = 0 \qquad (10'')$$

The summing up vertically over the number of equations and getting the constraint translates in 2 equations which allow us to establish shadow prices.

$$1-\lambda_y[y \; - x^*]-\lambda_e[e_h + e^r] = 0 \qquad (11a)$$

$$1+\lambda_y[y \; - x^c]-\lambda_e[e_h + e^e] = 0 \qquad (11b)$$

where:
λ_y and λ_e :shadow prices
x: are expenditure in the reference and e is energy in the reference.
r: stands for minimum consumption and c for absolute consumption.

From solving for marginal values λ_y and λ_e,, i.e. joint evaluation of energy and income, constraints are integrated in decision. The modified shadow price for energy can serve as reference for energy minimization. We have to approach the problem of energy use in food webs by a system perspective: the value is

$$\lambda_u = [[y \; - x^c][e_h + e^r]-[y \; - x^*][e_h + e^e]]/[x^c - x^* + e^r + e^e] \qquad (12)$$

For simplification, since we consider energy as measurement unit and later translate it in land, we have demand for energy or land delivery as energy:

$$\lambda_u = \xi_{h,o} + \xi_{h.1} e_h \qquad (12')$$

The relevance of the approach, given in (12'), can be judged against the fact that a simultaneous optimization of utility and energy prevails. But humans have to stick within an energy limit. The shadow price, λ_e vice versa, is a function of energy e_h. The energy minimization aspect is interwoven with utility. In fact the coefficients in (12') as energy demand reflect unit costs of losses in preying for food which is the measurement of prices in energy-food-webs. In other words given the pre-information, coefficients λ_y and λ_e can be calculated simultaneously. Taking the inverse of λ_e which is $\lambda_u = 1/\lambda_e$ and $\lambda_{y*} = \lambda_u / \lambda_e$ gives us results in the second equation. These results are used for equating. Finally, having λ_y and λ_e, we can calculate the consumption patter. Since they will be different from pure economics we take average of equation (8) and (10).

For an explanation: maximization of utility and minimization of energy are mirror-inverted activities. Finally we received marginal curves (criteria for optimality) as combination of preferences and constraints if we take a reference to the newly introduced energy constraint. This enables us to establish well-being, “utility”, as function similar to “needs” depending on energy. Note optimization is synonym to a function in ecological models of optimal foraging.

4 Modelling elephants

An elephant population which is representing competing nature (competing mostly for land and biomass) as key species is modelled as a system of net energy acquisition (shortened Eichner and Pethig, 2009). Elephants are characterized by diet and population size. Diet is a matter of “choice”. The choice is about energy spent to acquire energy needed for the body. At the same time the preference of the animal for taste and food getting technologies matters. This, together, is given by “technology”. Furthermore some constraints are to be met. A first constraint, in this regard, is about survival rates and population.
Survival in our simple approach is synonymous with maximizing the number of off-springs and body-mass. In this regard we follow Tshirrhart (2009). At a second layer, newly introduced, the goal is about improving growth (survival) in terms of water as limiting factor. Water resources can be augmented by humans. The level of water available to elephants shall depend on human labour. The underlying concept is that scarcity of water prevails and increased numbers of watering points helps elephants surviving. Survival of off-springs can improve. The elephants “choose” herbs, grasses, shrubs, etc. for nutrition.

In principle we have to make land and forage issue operational. In this regard, the analysis works with “energy prices” as been introduced by Eichner and Pehtig (2009). Energy from forage is given as “unit energy”, i.e. loss multiplied by species (grass) numbers consumed. The grass consumed is linked to land as percentage of occupied land. Taking this simplification net energy:

$$N_e = c_E E_E^{\eta_1} - \sum_g c_g l_g \qquad (13)$$

Emerges as objective. c_g's are average energy units, i.e. c_g's stand for energy spent. As been stated by Eichner and Pethig (2009) the c_g's are units of energy comparable to units of prices in economics (food webs). We call them prices, though being unit costs in an ecological modelling context; also we might consider them as capability of predatory to extract energy from prey. The below expression (14) is an objective to be achieved which is a surplus. This surplus is an indicator of wealth of elephants. Since it is impossible to work with numbers of grass, scrub, etc. and their unit weights in detail, we depict the problem at volumetric levels. It is expressed as land parcels and they are costs. Then further deliberations go with a generic technology given a land constrain:

$$A_T - A_H = E_E^{\eta_1} \prod_{i=1}^{b} e_j^{\eta_j} \qquad (14)$$

The analysis can be translated into average costs. Hereby two pathways can be explored: one of generic energy use and one of qualified energy. At the moment we present the generic one. Eventually later one can talk about specified energy. In equation (14) A_N is the area an elephant population needs for forage. A_H is the area occupation by humans to show the conflict between humans and elephants A_T is total area. The idea is that the elephants eat “bush”. The “bush” is a diet of elephants and it is composed of species (grass, shrubs, etc.). We translate biomass of species into elephant forage per hectare and measure it at a per-unit scale. Drinking water can be, to a certain extend, exchanged for water contained in forage species. We put a special emphasis on water as an important resource for our species. Then we minimize on notation:

$$N^e = \sum [l_j - g_j] e_j + E^{\eta_1} m_j w_j \qquad (13')$$

To modify (13) an emphasis is on biomass. Further given biomass as technology is summed up and the constraint (13’) prevails as well as biomass is (14’):

$$B_T = \prod_{i=1}^{b} B_j^{\eta_j} \qquad (14')$$

This has to be translated. We define the per capita (consumption) by dividing the organic matter for use “B” by the number of elephants (population)

$$B_T = B^{(1-\sum \eta_j)} \prod_{i=1}^{b} b_j^{\eta_j} \qquad (14'')$$

In (14’) the population size is a separate variable and any other variable for optimization is given as per unit size effect in provision. We specify the area needed for elephants in terms of an area measured which is defined in elephant units “e”. An elephant unit is exactly the area an elephant needs as a norm for survival correlated with the food unit needs. For example, let us say 10 ha is a norm. By this condition “bush” becomes equal to per unit area in the approach.

$$A_T - A_H = E_T^{-\sum \eta_j} \prod_{i=1}^{b} e_j^{\eta_j} \qquad (14''')$$

To understand the example: area measured in elephant units is 1000. I.e. instead of 100,000 ha we measure 1000 elephant-lands units. Then we try to figure in the water aspect. The idea is that water is a scarce resource for elephants and that the provision of water by humans can help the population to better survive. The extension is that elephant populations also spend energy on water acquisition. For this we have to amend the objective function as:

$$N^e = E^{\eta_1} [\sum_j [l_e - g_j] e_j + \sum \quad m_j w_j] \qquad (13'')$$

Again, the interpenetration is that a per-capita consumption of “bush” (species: grass, etc.) is needed as energy intake for elephants as well water. Concerning water, water extraction is correlated with herd size. We assume that all water is extracted. In that regard the problem reduces to energy spending, once more.

$$N^e = E^{\eta_1} [\sum \ [l_j - g_j - m_j \varpi_j] e_j + \varpi_n w_n E \qquad (13''')$$

The advantage of this standardized version is that optimization gives the behavioural conditions (below). The energy use, i.e. energy to feed the elephant population shall be minimized and a net surplus exists (Tschirhart, 2009). Then we add constraints. The optimization gives the shadow prices the constraints. Shadow prices for elephants are now measured in energy; the valuation is on constraints in eco-systems. -excursion: different grasses, etc. consumed are of lower trophic level than elephants; they have single valuation if we make energy use flexible as dependent on "supply", which means the strategy of plants is to avoid to be eaten, i.e. energy is spent to protect standing. End -

However, to keep things simple we start with the optimization of (16)

$$N^e = E^{\eta_1}[\sum [l_j - g_j - m_j \varpi_j]e_j + \varpi_n w_n E + \lambda_e [A_T - A_H - E_T^{1-\sum \eta_j} \prod_{i=1}^{b} e_j^{\eta_j}]$$

(16)

In equation (16) the "objective" (interest) of elephants is dependent on land, technology and land use valuation λ_e. Then, the procedure of optimization is similar to the one of humans if a logarithmic version of the constraint is used.

$$\partial N^e / \partial e_j = [l_j - g_j - m_j \varpi_j] - \eta_j \lambda_e e_j^{-1} = 0 \qquad (17)$$

This equation translates into a formulation of

$$\sum [l_j - g_j - m_j \varpi_j] \lambda_e^{-1} e_j = 1 \qquad (18)$$

if coefficients add up to 1 which is feature of chosen homogenous technology. Finally, since the total volume of organic matter surplus is given as

$$\sum l \ e_j - \sum [g_j - m_j \varpi_j] e_j = \lambda_e \qquad (19)$$

the surplus translates into the per capita weight of elephants, as gained, and at the level of balancing organic matter we receive an expression of land needed

$$\xi_T [A_T - A_H] = \lambda_e \qquad (20)$$

Note (20) is a residual of (19). The interpretation of equation (20) is those of a "demand" function for land based on shadow price. The shadow price depends on energy offered for feeding of elephants we can use it for equating.

5 System analysis and equating shadow prices

Essentially the calculation of the shadow prices is of importance for us. Now shadow prices shall be equated; i.e. the elephant shadow price is equal with the shadow price of energy for humans. For sure, this way of dealing with scarcity means a simplification because it reduces the issue to land required and. pursues the objective of energy acquisition equally. The approach is on need for energy of both, humans and elephants. Shadow prices after specifying are:

$$\xi_{a,h}[\xi_{h,0}/\xi_{h,1}+1/\xi_{h,1}]\lambda_u = A_H \qquad (21)$$

and assuming that the shadow prices should be equal on gets:

$$\xi_T[A_T-\xi_{a,h}[\xi_{h,0}/\xi_{h,1}+/\xi_h]\lambda_s]=\lambda_s \qquad (22)$$

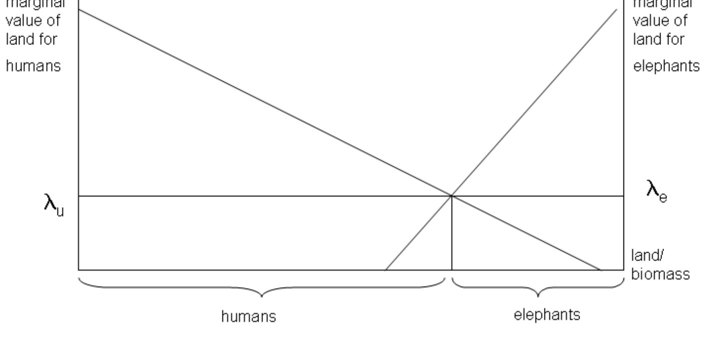
where $\lambda_s = \lambda_u = \lambda_e$

From this qualification, that the shadow prices for humans and nature in terms of biomass use should equate, we obtain a joint system-wise shadow price. (23)

$$A_T = [1+[\xi_{h,0}/\xi_{h,1}+/\xi_h]]\lambda_s \Leftrightarrow= \lambda_s = \xi_T^{-1}[1+[\xi_{h,0}/\xi_{h,1}+/\xi_h]]^{-1}A_T$$

The argument for a joint optimum can be derived from the following graphical exposition. The graphic shows two "demand" functions for land intersecting.

Diagram: Shadow price equating



First of all, the determination of the shadow price, as been conducted so far, should be interpreted as an allocation decision on land. In this respect the size of populations matters mostly. Hence, the land conflict issue is addressed simultaneously with valuation. To simplify and show the logic of deriving "demand" functions we reduce complexity by focusing on per capita consumption given populations. Given results of the per capita consumption a next step is to work with this per capita figure and optimize at the level of population. We suggest iterations. Having a reference for a micro-determination, at the macro-level, a new optimization problem occurs which can be clarified using again:

$$U = E^{\beta_2} X^{\beta_1} \prod_{i=3}^{n-1} (q_i - x_i)^{\beta_i} l^{-\beta_n} - \lambda_y [y - \sum p_i q_i] + \lambda_e [\sum m_i x_i + e_h] \quad (16)$$

For a further outline: we have to elaborate on the issue of normative and descriptive elements in the analysis! If the per-capita is given, the additional optimization is to determine the supply of water and population size. For this purpose the above complex objective function of humans can be reduced using a starting with the per capita consumption and shadow prices already received:

$$U = E^{\beta_2} X^{\beta_1} C^{\beta_i} [\xi_w w]^{-\beta_n} - \lambda_y^* [y^* - C\ X - r^w w^s] \quad (24)$$

the optimization gives for human population size is:

$$\partial U_h / \partial X_h = E_g^{\beta_2} (\beta_1) X_d^{\beta_1 - 1} C^{\beta_i} [\xi_w w_s]^{-\beta_n} - \lambda_y^* C = 0 \quad (25)$$

and water supply obligation:

$$\partial U_h / \partial w_s = -\beta_n\ E^{\beta_2} X^{\beta_1} C^{\beta_i} [\xi_w w]^{-\beta_n - 1} - r^w \lambda_y^* = 0 \quad (26)$$

Note, parallel, for establishing numbers of elephants in equilibrium we need a third equation. At the "supply" side of elephants we can work with the reduce objective from equation (13''') and assume that this equates with (25) which means that the animal population is exogenous to humans. Taking (13''')

$$N^{e} = E^{\eta_1} C + \varpi_n w_n E + \lambda_e^{*}[A_T - A_H - CE] \qquad (13''')$$

and optimizing we receive:

$$\partial N^{e} / \partial E \;\; = \eta_1 E^{\eta_1 - 1} C + \varpi_n w_n - \lambda_e^{*} C = 0] \qquad (27)$$

Equation (27) can be, for instance, plugged into (25) and the iteration should deliver a final result. Such new system of equations (25), (26), and (27: after taking logarithms and at macro-level) delivers a determination of the size of populations and water exchange. It is pending on per capita optimization done before which delivered shadow prices. In fact, in a feed-back loop population sizes and water delivery must be used to recalculate (optimize) the per capita consumption of both, humans and elephants. Recursively it feeds back into the macro-decisions, iterations could start which given the numerical equilibria. It means one can obtain after iterations a value balance amid conflicting partners.

6 Discussion

At this stage the analysis offers insight into “optimal sharing” of biomass. In this regard benefits for human are derived from elephants; perhaps this has to be specified in more detail. In the above specification elephants are an item of utility, not need. Hereby we pursue a soft version of consumption. Elephants might be an amenity as opposed to food. For this we could introduce payments. “Payment” comes with labour and we should detect a new shadow price for labour conserving elephants. The crucial thing is to detect variables which trigger the population and shadow prices. The habitat and food situation is considered equally crucial. The per capita (animal) availability of water and forage is considered a variable which is adjusting due to human intervention. Such type of a system analysis takes reference to scarcity problems of animals which can be relaxed by an “offer” as compensation for reduced access to resources. Assuming that water scarcity is constraining livelihoods and survival in harsh semi-arid areas we see labouring for water and delivered of water to elephants by humans as a relevant mean of compensation and adjustment. Perhaps there are other means. Deliberations require getting an indicator of scarcity or "troubles" for elephants as above (energy loss). The analogy of a market balance of energy loss prevails. A next step would be to involve the supply side of food which is so far not modelled. Then things are not only based on per capita consumption, but land and labour. This will bring a change in food price and prices dependent on shadow prices of the human and animal sector.

7 Summary and outlook

We outlined a system of energy pricing based on human preferences and needs as well as elephant energy assessment. Then we obtained joint shadow prices as ecological-economic valuation based on the inclusion of needs in human consumption and revelation of preferences. For humans and their adjustment, now based on modified to shadow prices instead of using only income, the usual perception is that prices are a medium of rationing. If prices depend on shadow price of biomass this also applies. In principle this new rationing means that only those individuals get food (by labouring for elephants), who have income and access to energy. This aspect has to be further elaborated. The condition is that the marginal benefit is greater equal to the price paid; so we need a fee or extra payment. Actually, with the exception of droughts and disaster, where people are starving and are dying from hunger, the system may work at good conditions, only, if prices are low. In the above analysis on humans we introduced population size as an endogenous variable for "decision making". This is a superficial way (depicting a Darwinist's position of selecting fittest). Yet, the number of users and per capita consumption of users can be modelled, simultaneously, building on such approach. Accordingly constraints are given by income and nutrients, as shown above; they have to supplement the analysis. In system oriented thinking food consumption is modelled as a rationing system, because feasible consumption and people interact. The final balance might be reached by migration and preferences for location.

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