Valuation of Specie: The Human-Elephant-Conflict

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Abstract

Land use conflicts between humans and nature are omnipresent. Typically valuation is done from a human perspective, i.e. anthropocentric, and it is based on human utility, i.e. not on nature wealth. We depart and include an energy loss minimization as a complementary optimization of nature and detection of "value" from behaviour. This value detection is combined with a system analysis on human-animal-energy-acquisition and the corresponding -conflict. In a system analysis on the conflict we equate biomass (energy) demand of humans with that of a species at the highest trophic level (for example elephants). The adjustment, reached for the equilibrium, is made allowing shadow prices to change. In this regard we emulate a social welfare analysis as if demands on land markets equate; we assume two different demand functions for land: human and animal. The allocation is considered optimal and delivers us "values".

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

Introduction

Land use conflicts between humans and nature are omnipresent. A matter of urgent analysis is the evaluation of species in terms of their importance for conservation and to secure survival under economic threats (Daily et al. 2011). Such aim is primarily important because it seems that only values make humans acknowledging nature (Everard, 2009). The current valuation theory prefers monetary valuation. Monetary valuation is conducted from the point of view of one "special" species (human) which "evaluates" its utility depriving another species (for example elephants) which competes with humans for land. The basis for evaluation is utility theory. Utility is a measure which is given as willingness to pay or acceptance of variations in provision of goods, for example food or species appearance, linked to land. But land use conflicts prevail. In the past, humans were capable to transfer biomass only to a certain extent into utility by hunting, gathering or farming. Nowadays, since humans have strong access to fossil energy, their acquisition potential is bigger. As a result humans have stretched out in land occupation and bio-energy acquisition by both, per capita consumption and population density per unit of land.

At the same time the evaluation of food and species depend on income levels. Especially income levels have risen tremendously, equally due to the use of fossils. Perhaps current willingness to pay is overestimated to income/money available. However, it can be stated that consumption has sharply deviated from the concept of basic needs. A conflict between preference as utility or fun and need for survival in determining consumption has emerged. A major question is how can humans in their evaluation of nature (as example elephants) been restricted (in food consumption) to assess "needs" rather than "preferences". In less pronounced ways, can one alternatively suggest compromises between utility and need? Working in ecological economics with "needs/energy" instead of "preferences/utility" poses a challenge to economists to find a compromise between preferences and needs, since they work with utility. The next question is how can we model a market of needs rather than a market based on preferences? The distinction between needs (Rauschmayer et al., 2011) and preferences is a building bloc for sustainability. The plea is that humans should look at needs instead of preference as in ordinary economics. Then a question is: can we compare needs and utility and in what "currency". If we want, for example, to recognize needs of prestigious species like lions or elephants, detect their demand for land and compare it with human needs, for food which is also a demand for land, what could be the equilibrium?

There is an immanent request to model the valuation of human and specie's needs as equilibrium and at the level of land conflicts; for instance, to look at the issue in terms of revealed "land prices". Because valuation as welfare measure in economic terms can be broken down to land valuation and animals, “welfare” can be expressed as sacristy in land. But, if values should be objective, it also requires finding the equilibrium between supply and demand. Then, if one speaks of equilibrium in demand for different demand alternatives, we get optimality, since the supply of land is fixed. In principle ant that is the idea of the paper, like on land markets, humans and other species compete for land and hereby we can simulate prices (marginal values). The normative aspect of valuation (pricing of the resource) is that in the equilibrium (game) there is no reallocation of resources which increase social welfare of cooperating units. So what is a social optimum in communities of humans and species? And what is a corresponding marginal value in land use of nature (conservation area or a natural park) as “price” humans should pay for (fields for food production)?

In the following analysis we will explore the condition for an equilibrium between prestigious species (for example elephant) and humans. The outline is as follows: First, the issue is explained 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” as well as elephants having needs for fodder and we determine population sizes. Third, the interaction is portrayed as exchange of labour/water for elephants who want water points and humans who want land which is needed for food and fibre. Fourth, 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.

Background and Proceeding

Normally the construction of equilibriums would imply a discussion on rights and institutional setting (Hanna et al. 1996). We avoid that and think about land markets on land market rights are traded. Actually there is a parallel of our approach in the determination of land prices and land rights. As for the determination of a land price which is a consequence of equating shadow prices of land, farmers, in a stylized land market approach, are 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 the land market: on land markets land constrains farmers who compete for it. Their competitiveness is determined by marginal profit functions. Hence we have to derive marginal “profit” or marginal “need” functions which are most relevant in our case and for which we which seek an ecological-economic optimum. In our model we outline marginal need functions, which have to be derived from stated objectives. Stated objectives are the 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 population size, energy contents of food, and labour economy as constraints which give the income of humans. The human side is furthermore specified as consumers receiving food from nature prised 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 nature side, which is represented by elephants, energy loss minimization is the suggested as objective function. I.e. a certain population of elephants which is supported by plants and water can be sustained. The population dwells on plants which are establishing and eaten as emulating supply of nature in a food web. Corresponding energy exchange prices emerge.

On the interaction between humans and nature as well as the suggested equilibrium, we work with a traditional adjusting of prices as based on surplus/deficits. Note that the economic shadow prices for humans and animals are of different nature and they may not equate. Rather the adjustment is taken by the adjustment of energy related shadow prices and species concordance. Species concordance is specified as co-incidence of “wished” or provided species levels from lower trophic levels. This modelling also makes a reference to a sub-model of human capacities to support the prestigious animal. Finally, the equilibrium is one of a derived optimality including fixed variables Then, we work with iteration: for humans (1) elephants are fixed which provide hunting meat, for elephants (2) humans are fixed who provide water. A fixed variable approach in this regard means that citizens (humans) can not decide on a variable "nature (elephants) because it is given exogenously (in our case by the equilibrium) to them. Though, it is becoming endogenous to the system, later. In this case shadow prices are changing for given constraints; but no mechanism is explicitly modelled. From point of view of the valuation it means that by adjusting the constraints we obtain the equilibrium, automatically, also the shadow prices are adjusting which will be shown.

Modelling humans

The modelling starts with a description of the consumption side of humans. We work with a traditional utility maximization approach which is used in neoclassical theory for deriving demand functions and specifying the 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 the revealed preference 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):

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

In the function we distinguish per capita consumption and population. The approach is an extension/modification of the usual multiplication of per capita and population (Daily et al, 1994). Since the 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 for 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, though the assumption remains the same that a “content free” utility maximization is delivering “demands” and prices of commodities. However, again, the theory of revealed preferences 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 seems fixed to consumers, but it is part of a preference as well as a preference (negative) exists for labouring. The preference function works with a minimum consumption. I.e. real preferences start above a level. 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 from labour as opposed to costs which are represented by the negative preference for working (below).

For getting quantifications of preference for elephants, it might be possible to establish a unit cost on basis of damage in food production system, which reveals costs, and to regress effects in the interactive utility function. Labour costs are perhaps the easiest way because the simple model used here is corresponding with a general farm household model in which utility is put above farm income (Sadoulet et al., 1998). Though, it is difficult to infer from observation to preference of non-market goods such as elephants, it might work.

Furthermore the assumption is that income is generated by labouring which depends on the prevailing wage rate.

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

Additionally we include a water quantity and price which is discussed below.

The question (i.e. one about embedding of the constraint in further physical conditions) is how much time and labour is devoted to support elephants.

This issue continues in another constraint. A second constraint is the land constraint. For simplicity land is separated for human use and elephants.

$$a^t = a^h + a^e \tag{3}$$

For the moment the number of humans and elephants shall be linked to these constraints, which will be discussed later. Then there is a necessity for readjusting 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 per person diet: The situation which is modelled refers to a situation of energy surplus for humans. This most relevant aspect enables to classify the preference as energy containing measure. However we have to find the value of the constraint. Note the value of the constraint is in the micro-optimization given as dependent on the energy availability for consumption. It has a shadow prices. In our scenarios we assume that the preferences determine the energy waste which is possible until an upper limit. Later we discuss a change in this limit and about further assumptions. However, we start with optimization: (5)

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

It means taking derivatives the general term is for a commodity i (6)

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

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

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

As a major problem is now, that the result depends utility and on two shadow prices. For this we have to eliminate them. Actually the two 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 that, in principle, an analogous objective function (9) is taken (9) which is the energy lost if the consumption is pursued. (9)

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

Though this equation is energy oriented it has a certain utility limit which has to be obtained from consumption. In such case optimization provides us with 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. Taking once more the summing up two 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 translates into two equations which allow us top establish the shadow prices λ_y and λ_e

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

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

where:
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 λ_y and λ_e the joint evaluation of energy and income constraint can be obtained. The modified shadow price for energy can serve as reference for the minimization of energy. We just approach the problem of energy use in a food web from a system level perspective given marginal value.

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

For simplification, since we consider energy as measure and later translate it in land, we have a marginal demand for energy or land delivering energy resp.:

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

The relevance of the approach, given in (12'), should be judged against the fact that a simultaneous optimization of utility and energy prevails. Humans have to stick within an energy limit. The shadow price, vice versa, is a function of energy e_h. The energy minimization aspect is interwoven with utility. In fact the coefficients in (12') reflect unit costs of losses in preying for food which is the measurement of prices in energy-food-web. In other words given the pre-information the 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 later-on used.

For an explanation the maximization of utility and minimization of energy are mirror-inverted activities. But we also need references. The approach starts with a reference to a minimum consumption of food items (crops). Then, it secondly commenced with consumption without energy limits as reference. Finally we receive a combination of preference and constraints if we take a reference to a new energy constraint. This enables us to establish well-being from utility as function similar to a function depending on energy. The optimization is synonym to a function in ecological models of optimal foraging.

Modelling elephants

The elephant population which is representing the competing nature (competing mostly for land and biomass with humans as in our virtual example) is modelled as a system of net energy acquisition (simplified from Eichner and Pethig, 2009). Elephants are characterized by their diet and population size. The diet is a matter of "choice". The choice is about energy spent to acquire energy needed for the body, i.e. energy spent by species grazed or browsed. At the same time the preference of the animal for taste and gathering technologies matters. This, together, is given by word "technology". Furthermore some constraints are to be met. A first constraint, in this regard, is one about survival.

Survival in our simple approach is synonymous with maximizing the number of off-springs or body-mass. In this regard we follow Tshirrhart (2009). A second layer, newly introduced, is about augmentation of technology (survival) in terms of water. Water resources can be augmented by humans. The level of water available to elephants depends on human labour. The underlying concept is that scarcity of water prevails and increased water (watering points) helps elephants and it can expected that water improves survival. To simplify, water is a resource been used as drinking water of elephants and its limiting herd size as well as it is included in forage, whereas the drinking can be augmented not water in forage. Hence, survival of animals (off-springs) can improve. The elephants, as humans, "choose" herbs, grasses, shrubs, etc. for nutrition. For humans one can perceive domestic animals which compete.

Elephants can receive water, i.e. provided with boreholes for water as a compensation, for instance to stabilize populations. At the same time they are of "use" for humans, i.e. being hunted. The outcome is a matter of reciprocity and rationality to preserve or consume and the value of that species matters. At this stage in the analysis, however, the issue of conflict and valuation as an instrument to make the conflict solvable. Humans and elephants may compete for forage and land, but they can also rely on each other. To model this aspect and look at a joint scarcity measure, which is grounded in energy optimization of systems, we have to address the issue by optimization of forage use and effort loss. Hereby things should be not too complicate in modelling. Hence we have to make the land and forage issue operational. In this regard, the analysis can work with “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 share or percentage of occupied land in a territory by either species. Taking this simplification a net energy balance emerges.

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

Here the c’s are the average energy units, i.e. the c_g’s stand for those spent. As been stated by Eichner and Pethig (2009) the c’s are units of energy comparable to prices in the economics of food webs. We call them prices in an ecological modelling context; consider them as the capability of predatory to extract energy from a prey. The above expression (13) is the objective to be achieved. 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 land use level. It is expressed as land parcels are the costs. The deliberations start 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 we can talk about specified energy. Where A_N is the area an elephant population needs for forage is the difference between human and total area. A_H is the area extraction by humans to show the conflict between humans and elephants. Then (1) the equation should correspond to a water balance. And (2) we have to explain how we derive it? 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 a most precarious resource for this species. Then we minimize on notation:

$$N^{e} = \sum [l_{j} - g_{j}]e_{j} + E^{\eta_{1}} m_{j} w_{j} \tag{13'}$$

To modify (13) the emphasis is on biomass. Given biomass as technology

$$B_{T} = \prod_{i=1}^{b} B_{j}^{\eta_{j}} \tag{14'}$$

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)

$$B_{T} = B^{-\sum \eta_{j}} \prod_{i=1}^{b} b_{j}^{\eta_{j}} \tag{14''}$$

Hereby, the population size is a separate variable and as another variable for optimization it is given as a norm in provision. We specify the area needed for elephants in terms of an area measured which is defined in elephant units. An elephant unit is exactly the area an elephant needs as a norm for its survival. For example, let us say ten ha is the norm. By this specification the "bush" becomes equal to a per unit area in approach.

$$A_{T} - A_{H} = E_{T}^{-\sum \eta_{j}} \prod_{i=1}^{b} e_{j}^{\eta_{j}} \tag{14'''}$$

To continue the example: area measured in elephant units is 1000. I.e. instead of 100,000 ha we measure 1000 elephant unit areas. As been indicated: such way of doing it gives a measure on human impact on elephants.

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 humans can help the population to better survive. The extension is that the population spends energy on water acquisition. For this we have to amend the objective function as:

$$N^{e} = E^{\eta_{1}} [\sum_{j} [l_{e} - g_{j}]e_{j} + \sum m_{j} w_{j}] \tag{13''}$$

Again, the interpenetration is at a per-capita consumption of "bush" species needed as energy intake for elephants and additionally water. Concerning water, total 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.

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

The advantage of this standardized version is that the optimization gives the behavioural conditions (below). The energy use to feed the population shall be minimized and a net surplus exists, as it is presented in system analysis on trophic levels (Tschirhart, 2009). Then we have to add constraints. In the optimization this gives the shadow prices for the constraints. Shadow prices are the valuation of constraints in eco-systems. In fact the different species consumed of lower trophic level by elephants can have a single valuation if we make energy use flexible as dependent on it the "supply" side which means the strategy of plants to avoid to be eaten, i.e. energy is spent to protect standing. However, to keep things simple we start with the optimization of (16)

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

In equation (16) the objective 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 the coefficients add up to 1 which is a feature of the chosen technology being homogenous. Since total volume of organic matter surplus is given as

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

this surplus translates into the per capita weight of an elephant and at the level of balancing organic matter we receive an expression of land needed

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

The interpretation of the equation is those of a "demand" function, since the shadow price depends on land/biomass available for the feeding of elephants.

System analysis and equating shadow prices

Essentially the calculation of the shadow prices is of importance. 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 in the system means a simplification because it reduces the issue to land required and. pursues the objective of energy acquisition. The parallel approach is need for energy of humans. In a nutshell on equating shadow prices after specifying

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

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

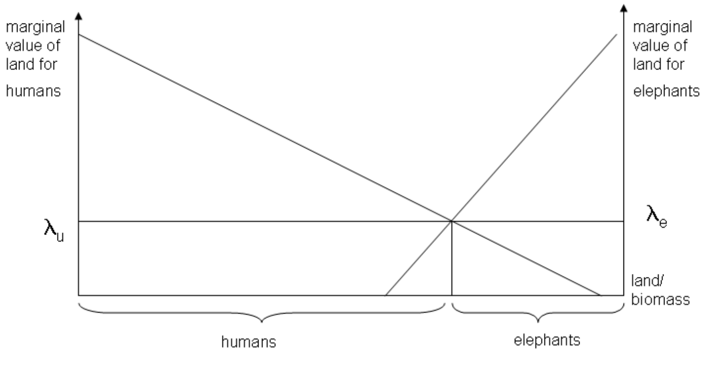
$$\xi_T [A_T - \xi_{a,h}[\xi_{h,0} / \xi_{h,1} + / \xi_h]\lambda_s] = \lambda_s \qquad (22)$$

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



Source: own drawing

First of all, the determination of the shadow price, as been conducted so far, should be interpreted as an allocation decision of land. In this respect the size of populations matters. To simplify and show the logic of deriving the "dema-nd" functions we have reduced complexity by focusing on per capita consumption. Given a result of the per capita a next step is to work with the per capita and optimize at the level of population and exchange. 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 (6):

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

For a further outline: we have to elaborate on the issue of normative and descriptive elements in the analysis! 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 received. Using:

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

the optimization gives for human population size :

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

and water supply

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

Note for establishing the number 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:

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

which could be, for instance, plugged into (25). This new system of equations (25), (26), and (27), after taking logarithms and being at the macro-level, delivers a determination of the size of human population, elephant population and water delivery. It is pending on the per capita optimization done before which delivered the shadow prices. In fact, in a feed back loop the population sizes and water must be used to recalculate (optimize) the per capita consumption of both, humans and elephants. Recursively feeding back into the macro-decisions several iterations start which gives the numerical equilibrium. It means one can obtain after iterations a balance between conflicting partners.

Discussion

As it stands the analysis offers an optimal sharing of biomass. In this regard the benefit for humans from elephants has, in particular, to be specified in more detail. In the above specification elephants are an item in the utility function. Hereby we pursue a soft version. Elephants might be a public good as opposed to food. For this we could introduce payments. The “payment” comes with labour and we should detect a change in shadow prices 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 crucial. The per capita (animal) availability of water and forage is considered a variable which is adjusting due to human intervention. This type of a system analysis takes reference to scarcity problems of animals (shadow prices for biomass) which can be relaxed by an “offer” as compensation for reduced access to other resources. Assuming that water scarcity is a constraining the livelihood and survival in harsh semi-arid landscapes, we see labouring for water and delivered of water to elephants by humans as a relevant mean of compensation and adjustment. This requires getting an indicator of scarcity or “troubles” for elephants as done above. The analogy of a market prevails.

Simulations on food price change due to land scarcity matter. The next step is to involve the supply side of food which is then not only based on the per capita consumption, but land. This will bring about a change in prices for food and prices dependent on the shadow prices of the human and animal sector.

Summary and Outlook

We outlined a system of energy pricing based on human preferences and needs as well as elephants energy assessment. Then we obtained joint shadow prices. For humans and their adjustment due to shadow prices, the usual perception is that prices are a medium of rationing. If prices depend on the shadow price of biomass this also applies. In principle this new rationing would mean that only those individuals get food, by labouring for elephants, have income. This aspect has to be further elaborated. The condition is that the marginal benefit in the utility function 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, if prices are higher. In the above analysis on humans we introduced the population size as an endogenous variable for "decision making". Actually this is a superficial way of depicting Darwinists' position of selecting the fittest. However, the number of users and the per capita consumption of these users can be modelled, simultaneously, building on the approach. Accordingly constraints given by income and nutrients, as shown above, 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 preference for a location.

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