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# On discount rate and intertemporal choices for land allocation: a new approach

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## 1. Introduction

The discussion on discount rates is not new in the economic literature. Well-known economists such as Arrow (1963, 1965, 1996), Solow (1974), Sen (1967), Dasgupta, Maler and Barret (1999), Samuelson (1980), Weitzman (2001,), Ostrom (1990)) or Lind (1982), (Zeckhauser and Viscusi, 2008) have devoted great efforts to understanding how economists can reconcile the wellbeing of present and future generations. More recently, and specifically in the context of climate change the debate on discount rates has acquired a major importance. Specifically in the context of climate change the Stern report (Stern et al, 2007), supporting the use of rates close to zero on the grounds that future generations might well not exist, has triggered the answers of scholars such as Nordhaus (2007) who argues for much higher rates an criticizes the values used by Stern are a serious weakness of his report.

In general, however, leading scholars have argued for lower discount and possibly declining rates when addressing the climate change problem. These include the following:

- Chichilnisky (1997) introduces two axioms for sustainable development, which, in combination, require that neither the present nor the future should play a dictatorial role in society's choices over time. The implications of her formula of discounting is that the future will be discounted in a conventional manner in the near future, but after a point- the so-called 'switching date'- remaining effects will not be discounted at all (i.e. at a zero rate).

- Li and Löfgren (2000) consider two individuals with identical preferences in all areas except one: they have different values for ρ, the personal rate of time preference (see equation (1). The overall societal objective is to maximize a weighted sum of utility for both of them. The result of this weighting practice is similar to that of Weitzman's discounting- the individual with lower discount rate is given dominant weight as time goes by and the collective discount rate is declining.

- Weitzman (2007 and 2008) defends that even negative discount rates are arguable due to the high consequence (low probability) expected costs in the future; Weitzman (2007)

- Tol and Yohe (2006, 2009) suggest that Stern might be right but for the wrong reasons and that the use of low rates if time horizon is extended can increase damages very substantially.

- Summers and Zeckhauser (2008) use psychological principles to suggest four dimensions for climate change policies and low but not negative discount rates.

- Dasgupta (2008) argues that "discount rates ought instead to be derived from economic forecast and society´s conception of distributive justice concerning the allocation of goods and services across personal identities, time and events" and proposing that an optimum policy may well not exist. He argues in favour of the use of very low discount rates on the basis of the future income inequalities.

- Gollier (2008) argues for a systematically declining discount rate justified on the basis of future shocks on economic growth going from ranges close to 4% for 100 years periods to 1-3.5% ranges for 1000 year periods. The purpose of this note is to make a practical proposal for determining the discount rate for projects or programmes in which one of the options is to maintain or improve land in its natural state. At present economist working on such problems sooner or later has to deal with the difficult decision of choosing an appropriate discount rate and while some governments now offer quite precise advice it is still controversial and does not have wide agreement2.

This is the starting point for the proposal and the analysis presented in this paper. We recommend a simple and trustable methodology to choose a discount rate when designing and evaluating conservation options. For this purpose we set the ground from a very simple ethical rule: ***any policy maker should try to value similarly and consistently a piece of land that is in a natural state with another one has been designated as appropriate for development (namely***

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[1] There is a problem with declining discount rates, namely the possibility of time inconsistency. 'Time inconsistency' refers to the situation where plans made at one point in time are contradicted by later behaviour. For example, as Guo (2004) notes, "if a government decides to use high discount rates for the near future but lower ones for the far future, the immediate large spending will be easily justified. However, when later governments review the policy, they may conclude that this earlier policy was not optimal and decide to increase the discount rate again, which will lead to higher consumption than planned." Heal (1998) has shown that almost all types of declining discount rates result in time inconsistency.

[2] The biggest attempt has been made by the UK Treasury in its Green Book 2003, where the recommended social discount rates are declining with time. The current recommendation is to use rates of .5% for periods of zero to 30 years, declining to 1% for periods of over 300 years. Similarly, France decided in 2004 to replace its constant discount rate of 8% to a 4% discount rate for maturities below 30 years, and a discount rate that decreases to 2% for larger maturities. Theres is not, however, an EU-wide recommendation, or one that applies to other developed and developing countries.

***for urban use, with the permission to build on it). This is based on the believe that protected areas are worth at least as much in the long run as developed areas, and improvements to the former should be evaluated using a discount rate that has been determined on the basis of this principle.***

This assumption implies giving the same weight to both lands which assumes that future generations would give the same importance (and the same economic value) to natural land as to the land for urban use, as a minimum. This statement has the advantage of avoiding making other uncertain assumptions about the expected welfare or growth rate of consumption of future generation (implied in the Ramsey rule), and the magnitude of the projected impacts of climate change (which might turn to be wrong in future realities).

The rest of the analysis follows from this and is explained in section 2 making the case for the calculation of appropriate discount rates for land-related assets taking into consideration local conditions and social preferences. Something close to the proposal by Ostron but with additional practical and empirical details added. Section 3 of the paper is devoted to illustrating the proposition with the information collected from several natural asset valuation studies. Finally, the last section offers some concluding remarks.

## 2. Conceptual set up: making the case

### *Hypothesis*

Let us assume the following situation in time period zero (t=0). There are two pieces of identical land areas of one hectare named N and U. Both have the same environmental and site-characteristics attributes such as location, slope, orientation, proximity to infrastructures or any other. In this case the value of N and U would be equal, and it could be represented by a price PRRRR$_N$ and $P_U$ if a market exists for both lands.

$$P_N = P_U$$

Now let us assume that in time period 1 (t=1) an administrative procedure grants U the right to be built upon. U becomes urbanized while N stays natural. That is, U is granted the possibility to have industrial, commercial or residential construction. This will automatically increase the market price of U significantly (maybe 10 to 20 times higher). Thus,

$$P_N \ll P_U$$

This situation is relatively common in most countries where a "well informed" government decides to grant building rights to different pieces of land. When this occurs, any situation in which a decision has to be taken about the either tract of land will be heavily influenced be the higher value attached to U. Taking into account future generations opens the discussion on the discount rate that should be used for this purpose. If both pieces of land stay forever as in t=0, future generations will value both N and U in the same way. If they stay forever as in t=1 the market interest rate will play a role for the calculation of the present value of U (PV). But it is not so clear which is the rate that should be used to value the natural land.

While for urban land the market interest rate is normally used, for natural land the question is which discount rate should be used? What this paper proposes is a basic rule to calculate the discount rate that should be used when valuing natural assets. We argue that **the discount rate to be used for N in any analysis is the one resulting from assuming the same present value for both N and U**. In the case of U, for which a market exists, this will be $P_U$, the price per hectare observed in the market. For N, which has environmental values not traded in the market, this value is usually calculated using non-market valuation methods and is represented by the $PV_N$ per hectare.

That is,

$$i_N^* \ will \ that \ resulting \ from \ PV_N = P_U$$

Using the formula for the calculation of the present value,

$$(1) \ PV_N = \sum_0^t \frac{(V_N)_t}{\left(1 + i_N^*\right)^t} = P_U$$

Where $V_N$ is the annual value per hectare (flow) of N which can include both use and non-use values taken from stated or revealed preference approaches, and $i_N$ is the discount rate for natural assets. Use values are derived for example from the individual willingness to pay to visit the natural site (contingent valuation or choice experiments) or from the households' expenses actually supported for the visit (travel cost). Non-use values are expressed in terms of the willingness to pay to protect the natural asset and preserve its biodiversity level (existence value).

### *Calculation*

The calculation of $i^*_N$ results from the solution of equation (1) and relies on numerical or graphical methods (REF), being based on the same conceptual framework of the "Internal Rate of Return" IRR. $i^*_N$ is the discount rate at which the present value of the natural assets equals the price of the land for urban use (with permission to build).

If t=1 and $V_N$ constant over time then equation (1) can be written as follows:

$$PV_N = \sum_{0}^{1} \frac{(V_N)_t}{(1+i^*_N)^t} = V_N + \frac{V_N}{(1+i^*_N)^1} = P_U$$

Solving for $i_N$ we get:

$$(2 + i^*_N)V_N = (1 + i^*_N)P_U$$

$$\frac{2V_N - P_U}{P_U - V_N} = i^*_N$$

If t=2 and $V_N$ constant over time, $$PV_N = \sum_{0}^{2} \frac{(V_N)_t}{(1+i^*_N)^t} = V_N + \frac{V_N}{(1+i^*_N)^1} + \frac{V_N}{(1+i^*_N)^2} = P_U$$

Thus, solving for $i^*_N$:

$$\frac{i_N^2 + 3i_N + 3}{(1+i_N)^2} = \frac{P_U}{V_N}$$

For any t the equation will be,

$$PV_N = \sum_{0}^{t} \frac{(V_N)_t}{(1+i_N)^t} = V_N + \frac{V_N}{(1+i_N)^1} + \cdots + \frac{V_N}{(1+i_N)^t} = P_U$$

The sequence of discounted flow values of N is a polynomial function with n degree, so that finding $i^*_N$ that equates $P_U$ and $PV_N$ requires us to find the roots of the polynomial. Different methods can be used for this purpose, such as the linear interpolation using trials and error methods or the Newton-Raphson method. The first allows is simpler but allows only an approximation of the discount rate, while the second uses algorithms to find successively improved approximations to the roots of the function (Tjalling and Ypma, 1995).

## 3. Illustration

In any given situation as the one presented above one expects that the discount rate of U ($i_U$) will be determined by the market interest rate and that the $P_U$ will also be known. On the other hand, let us assume that we have estimated (through stated or revealed preference methods) the value per hectare per year of a natural site N ($V_N$).

A simple illustration applying the rule for t=1 is the following:

$V_N$ = 15,000 $/ha/yr constant over time.

$P_U = 29{,}000$ $/ha

Then

$$PV_N = \sum_{0}^{1} \frac{(V_N)_t}{(1+i_N)^t} = V_N + \frac{V_N}{(1+i_N)^1} = 29{,}800$$

$$i_N^* = 0.004 \approx 0.4\%$$

If t=2:

$V_N$ = 15,000 $/ha/yr constant over time,

$P_U = 45{,}500$ $/ha

Then

$$PV_N = \sum_{0}^{2} \frac{15{,}000}{(1+i_N)^t} = 15{,}000 + \frac{15{,}000}{(1+i_N)^1} + \frac{15{,}000}{(1+i_N)^2} = 45{,}500$$

Solving the second order polynomial function we get:

$i_N^* = -0.006 \approx -0.6\%$ (discount rate close to 1 but in this case at a negative rate).

The recommendation is that this above discount rates should be used to evaluate any programmes or polices that change the ecosystem services generated within the land area in question.

### 3.1 Application to specific case studies

In order to illustrate some practical examples, we have identified a number of case studies (selected from peer reviewed literature), conducted in different regions, assessing annual non-market values per hectare for different types of habitats or natural ecosystems. For this purpose the Total Economic Value (TEV) should be taken into account in the calculation of the present value of the natural site, which includes all the benefit categories of use and non-use values (direct and indirect use, option, bequest and existence values). This is the most comprehensive non-market value that should be compared with the market value of the land. The TEV is estimated as an annual flow value. In some cases, expectations of changes in this value over time are given. Over time flow can be expected to increase in real terms as a result of growing real incomes and an increasing scarcity of services from natural capital (Krutilla, 1967). Hence we calculate the implicit discount rate under two assumptions: (a) that future flow values are equal to the present ones and (b) future flow values grow at the rate of expected growth or real per capita incomes (under A2 and B2 IPPC scenarios).

For each case study we have estimated the discount rate $i^*_N$ that would result from the application of the suggested rule, calculated using a linear interpolation with trials to approximate its real value. In the exemplification we assume a time frame of 100 years, when intergenerational issues about the discount rate emerge. As regards the price of the land for urban use, this is the average price observed in the market for the land located in the vicinity of the case study site. The estimated discount rate for each case study is reported in Table 1 here below.

**Table 1. Proposed discount rates for different case studies.**

| Study | Country | Habitat | Value/ha/yr (standardized $2000) | Price/ha land for urban use ($2000) | Estimated $i^*_N$ (%) Constant flows | Estimated $i^*_N$ (%) Increasing flows (IPCC A2) | Estimated $i^*_N$ (%) Increasing flows (IPCC B2) |
|---|---|---|---|---|---|---|---|
| Prestige Report (Galarrage et. al,...) | Spain (Basque coast) | Sandy and shingle beaches | 87,600 (mean) | 5 million | 1.28-1.29(>0) | 2.79-2.8(>0) | 2.52-2.53(>0) |
| Hoyos et al. (2007) | Spain (Basque country, Jaizibel montain) | Terrestrial habitats (interdital, protected) | 73,428 (mean) | 5 million | 0.853-0.854(>0) | 2.35-2.36(>0) | 2.05-2.06(>0) |
| Costanza (1997) | North America | Mangroves | 2,228 (mean) | 6 million | 4.52-4.53 (<0) | 3.11-3.12(<0) | 3.54-3.55(<0) |
| Hanley et al. (2002) | UK | Temperate forests (all types) | 1,870 (mean) | 3 million | 4.11-4.12 (<0) | 2.7-2.71(<0) | 3.13-3.14(<0) |
| Hanley et al. (2002) | UK | Temperate old forests | 3,048 (mean) | 3 million | 3.5-3.51(<0) | 2.08-2.09(<0) | 2.5-2.51(<0) |
| Scarpa et al. (2000) | UK | Temperate forests | 883 (mean) | 3 million | 5.08-5.09(<0) | 3.68-3.69(<0) | 4.12-4.13(<0) |
| Scarpa et al. (2000) | Ireland | Temperate forests | 1,652 (mean) | 3 million | 4.26-4.27(<0) | 2.85-2.86(<0) | 3.28-3.29(<0) |

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|---|---|---|---|---|---|---|---|
| Aakerlund (2000) | Denmark | Temperate forests | 358 (mean) | 3 million | 6.0-6.1(<0) | 5.1-5.11(<0) | 4.65-4.66(<0) |
| Bellu et al. (1994) | Italy (Liguria) | Mediterranean and temperate forests | 1,023 (mean) | 3 million | 4.85-4.86(<0) | 3.87-3.88(<0) | 3.43 -3.44(<0) |
| Mogas et al. (2006) | Spain (Catalonia) | Mediterranean forests | 404 (mean) | 5 million | 5.9-5.91(<0) | 4.96-4.97(<0) | 4.51 -4.52(<0) |

The estimated discount rate depends on the magnitude of the original annual value per hectare, as well as on the average price per hectare of the land for urban use in the vicinity. In order to simplify the analysis, the period of time is constant, 100 years. The method thus accounts for local particularities when having to select the discount rate. Logically, the closer the values from the local reality the better will be the estimates.

In the reported case studies, the discount rate is generally very small. In fact it is negative in most of the cases, as the non-market value of the site assessed in the study is quite low compared with its market value. On the one hand, it is true that some of the values are underestimating the TEV as they include only some of the benefits of the site. On the other hand, however, it must be acknowledged that the annual values per hectare selected for our exemplification (including TEV) are quite high compared to the values usually available from the literature.

We do not claim that a negative discount rate should be always applied when valuing natural assets, but that the appropriate discount rate should be the one resulting from having the same present value for natural land and land for urban use. That is, equivalent treatment is given to identical natural assets. The discount rate could also be positive as in the two case studies reported for the Basque Country, where the estimated non-market values are quite high.

The Total Economic Value per hectare reported from stated or revealed preferences depend on many factors, such as the site physical characteristics (biome, habitat), the socio-economic variables (income per capita, population, etc), the relative importance of the different types of benefits (use and non-use), as well as the valuation method used. All these variables are influencing the values per hectare which are very site-specific. The appropriate non-market value to be used for a natural site should therefore be selected taking into account the context-specific variables identifying the territory (site and socio-economic characteristics). This requires a specific knowledge of the territory at a local level. The proposed method to identify the discount rate for natural assets is therefore based on the individual preferences which in turn depend on the site characteristics and the socio-demographic features of the area.

We suggest the following steps to estimate the appropriate discount rate. First, we have to select the most suitable case study which should be representative of the territory under analysis (in terms of habitats). The selection should take into account only TEVs or good approximation of TEV. Second, we need to identify the average price of urbanized land in the same territory, which should be the closest as possible to the natural site of the case study. Third, we need to make an assumption of the rate of growth of future flows of services from the land. Based on these we calculate the discount rate at which the present value of the natural site equals the average price of the urbanizable land. This discount rate can be used then in all the choices concerning programmes or polices that relate to the use of the land in the territory where the case study is located. The territory should be defined in terms of habitats or ecosystems. For example, the Jaizibel mountain (valued by Hoyos et al, 2007, Table 1), located in the Basque country in North of Spain, is representative of all the terrestrial habitats of the Basque coastal zone, and the discount rate estimated for this site can be used for all the terrestrial habitats in the coastal areas of the Basque country when a decision has to be taken about this area (to protect it or for any other reason).

The discount rate estimated through the proposed procedure will depend on the non-market flow values of the natural site under concern (which in turn depends on the type of habitat, as well as on the site- and context-specific variables), on the price of the urbanizable land in the same territory, and on the time frame considered (number of years).

## 4. Conclusive remarks

Identifying the appropriate social discount rate is crucial for policy action especially in the context of long-term environmental risks, such as those posed by climate change, involving a high degree of uncertainty. In addition, we have to deal with uncertainties related to future economic growth.

Two critical arguments should be taken into account in the discussion about the choice of the discount rate in intergenerational choices about the environment. The estimation of the discount rate in the welfare approach is based on the fact that future generation will be richer than ours, according to which *"one should not be ready to pay one euro to reduce the loss borne by future generations by one euro, given that these future generations will be so much wealthier than us"* (as mentioned by Gollier, 2008). However, in the current situation of uncertainty, we cannot say with certainly that global GDP is expected to continue to rise over the next 100 years. In this context, the definition of the discount rate cannot be based on expectations about future economic growth. Second, according to the decreasing marginal utility theory, if a resource becomes scarcer, its value is expected to raise compared to the less scarce resources. Some natural ecosystems (such as wetlands, mangroves, coral reefs) can become very rare in the future, and this would increase their value and the price of the corresponding land. In the most extreme case that human life would be threatened due to the disappearance of critical natural ecosystems, the value of these ecosystems might see a dramatic escalation, to the point of reaching some critical threshold where the notion of economic value itself would become meaningless. In a situation of higher scarcity of natural resources in the future, if the governments would be willing to invest in these resources for protecting their natural ecosystem, they will have to pay a much higher price. So we can reasonably think that low social discount rates (giving today high present values) could be reflected in higher actual prices of natural lands in the future.

What we propose in this paper simplifies the discussion about which discount rate should be used under the current level of uncertainty characterising climate change impacts and long-term risks to future generations. The current *"main intellectual battleground is whether we should be* *using discount rates in the range of 3% or discounting by only a token nonzero amount, such as 0.1%"*, as mentioned by Zeckhauser and Viscusi (2008).

The suggested approach is assuming that the society is making the decision about investments to protect the environment, and not the individuals. This places our discussion about the discount rate in the "societal-normative box" (Zeckhauser and Viscusi, 2008).

The results reported for the case studies taken into account in this paper show that the discount rate resulting from the application of the above mentioned rule is very low, or even negative. This means that we are assuming that future generations might give a higher weight to the natural assets than today's generation. This is reflected in much higher present values of natural assets compared to their current price on the market. If these present values are taken into account by the governments in their investment decisions about natural lands, this would support policy decisions more oriented towards the protection of the environment.

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