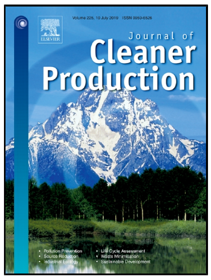
Accepted Manuscript



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PII:	S0959-6526(19)31633-6
DOI:	10.1016/j.jclepro.2019.05.107
Reference:	JCLP 16872
To appear in:	*Journal of Cleaner Production*
Received Date:	05 September 2018
Accepted Date:	10 May 2019

Please cite this article as: Ambika Markanday, Ibon Galarraga, Aline Chiabai, Elisa Sainz de Murieta, Bosco Lliso, Anil Markandya, Determining discount rates for the evaluation of natural assets in land-use planning: an application of the Equivalency Principle, *Journal of Cleaner Production* (2019), doi: 10.1016/j.jclepro.2019.05.107

Determining discount rates for the evaluation of natural assets in land-use planning: an application of the Equivalency Principle

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*This paper has not been submitted elsewhere in identical or similar form, nor will it be during the first three months after its submission to the Publisher.

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Abstract

One of the most pressing issues when making decisions over long-term environmental problems is deciding on an appropriate discount rate. This can be a highly technical discussion. While some argue in favour of market rates, which usually tend to be high, others support the use of near-zero rates to ensure that both current and future generations are properly accounted for. This paper presents an alternative approach to determining the discount rate for environmental assets in the case of land-use planning - the Equivalency Principle (EP) - based on the normative proposition that the social value of protected natural land should be at least the same as the market price of an adjacent land with similar environmental characteristics that has been granted permission for development. The paper first provides a theoretical overview of the approach, followed by an application of the EP at the land plot level across 11 European countries. Based on the EP, pure rates of social time preference that would equate natural and development land values within each administrative unit have been calculated. The findings show that the application of the EP usually results in discount rates that are lower-than-market rates and that are geographically differentiated. This implies discount rates that account for preferences of the society where the land or natural resource is located, with results ranging between 0% and 11%, with an average rate of 1% across study sites.

Keywords: Discounting; land-use planning; equivalency principle; sustainability; sustainable development; sustainable land-use

1. Introduction

Decisions with consequences that occur over the long-term are widely known in economics as *inter-temporal choices.* Indeed, inter-temporal decision-making has been studied during the last 80 years through the Discounted Utility (DU) model, formulated by Paul Samuelson (1937). The DU model assumes that society prefers to receive benefits in the short-term while delaying costs to the future, by "exponentially discounting the value of outcomes" as they occur further in time, thus placing decreasing weight on the value of future welfare. However, if lower discount rates give higher value to future generations more likely to suffer from environmental impacts, but come at a cost of greater economic sacrifices to the current generation, then what is the most appropriate discount rate to use?

The classical framework for representing inter-temporal choices has been widely disputed over the years for the use of market rates. Bromley (1998) says that traditional sustainability approaches based on commoditising natural assets, and making judgements of welfare and utility across generations (and across infinitely many time periods) cannot stand because the desires, valuations and preferences of future generations are totally unknown and unknowable to us. Based on this, Bromley asserts that we should follow rights-based approaches to sustainability wherein those living now agree to preserve 'settings and circumstances' for the future. Gowdy (2004) on the other hand, argues that based on the considerable evidence showing that people value the medium and distant futures the same (hyperbolic discounting), straight-line discounting (whereby the future is discounted at the same rate during all future time periods) may seriously underestimate the benefits of long-term environmental policies. After a comprehensive discussion on environmental discounting in his book *Greenhouse Economics: Value and Ethics,* Spash (2002) boils the debate down to one between ethics and economics. While acknowledging this, he ascertains that: '*The contradiction is that economics takes a very specific philosophical and ethical position and then tries to deny the relevance of ethics in economics. The conflict of values remains despite the attempts to remove their explicit discussion from the economic debate"* (Spash, 2002, p. 188). A significant milestone came in 2007 with the *Stern Review on the economics of climate change*, which advocated for the use of near-zero discount rates for representing intergenerational preferences on climate change (Stern, 2007). Its publication received mixed reviews. Several leading economists, such as

Dasgupta (2007) and Weitzman (2009), agree wholly with the use of low discount rates given the inadequacy of traditional neoclassical frameworks for addressing environmental issues characterised by irreversibility, uncertainty and long-term horizons. Others, while agreeing on the need for action on climate change, considered the *Review* incomplete and its conclusions ambiguous from an economic perspective (Tol, 2006; Tol and Yohe, 2006). Indeed, in his appraisal, Nordhaus (2007) argues that the *Review* confuses two fundamental concepts of discounting. The first, defined as the "real interest rate", relates to the annual percentage increase in the purchasing power of a financial asset, measured by the nominal or market interest rate on that asset minus the inflation rate (Frank et al., 2007). The second, called the "pure rate of social time preference", is concerned with the economic welfare of households or generations over time. It describes the rate at which society is willing to postpone a unit of current consumption or expenditure in exchange for future consumption. The pure rate of social time preference has been proposed as a social discount rate for public projects in general, given the consideration of intergenerational equity for long-term projects (Scarborough, 2011). Therefore, unlike the real interest rate, which deals with future goods or investments, the pure rate of social time preference involves the discounting of future welfare. In this case, a discount rate of zero would ensure that present and future generations are treated equally, whilst a positive rate would imply a reduction in the value placed on the welfare of future generations compared to the present generation.

When discussing the use of near-zero rates proposed by Stern, or Nordhaus's support of real (market) interest rates close to 6% per year, Beckerman and Hepburn (2007) assert that the choice of either alternative is not trivial, and may have a decisive influence when assessing the economics of climate policy. Instead, they propose an intermediate approach based on the use of stated preference surveys, behavioural experiments and methods for determining discount rates reflective of social preferences. Conversely, Philibert (2006) proposes to assign a growing value over time to environmental assets that are not substitutable and not reproducible, or alternatively, he suggests the use of declining discount rates to account for the uncertainty of future economic growth. Others, such as Cropper and Laibson (1998), Gollier (2008) and Groom (2014) agree with Philibert's assertion of declining rates. Chichilnisky (1996) argues that no generation should prevail over the other, and similarly proposes the use of a conventional, market-based, discounting approach in the near-future and a rate of zero after an inflexion point. Certainly arguments for the use of declining discount rates are often justified on the basis of: uncertainties related to market-based rates or behavioural changes in the long-term, or due to the aggregation of heterogeneous pure rates of social time preference. It seems that during the last decade a non-official consensus has been reached in favour of social discount rates that decrease in the long-term (Groom, 2014).

Since the early 2000's the notion of dual-discounting has been emerging as a way to value environmental goods and services separately and differently from other costs and benefits (Tol, 2003; Yang, 2003). For example, Gollier (2010) argues in favour of an ecological discount rate smaller than the economic discount rate, where he estimates that changes in biodiversity be discounted at a rate of 1.5%, while changes in consumption be discounted at a higher rate of 3.2%. By separating the environment from other market goods and services, the approach ensures that future environmental assets are not undervalued or that the [economic] discount rate applied to them is not too large (Gollier, 2010). Indeed, as Weikard and Zhu (2005) argue dual rate discounting can be justified in cases where future prices for environmental goods are unavailable, or when market goods and environmental goods are not substitutable. This seems reasonable given that many environmental restoration or enhancement projects carried out by governments would be otherwise unable to meet decision-making criteria based on conventional CBA and discounting practices (Almansa and Martínez-Paz, 2011). But Green and Richards (2018) argue that the way that humans value monetary goods should not be confounded with the way they value environmental goods. Indeed, in their paper based on experimental evidence, the authors find that individual discounting behaviour, while varying widely across environmental goods, generally tends to be exponential, such that individuals discount environmental goods at lower rates compared to monetary goods. The evidence-base suggests that humans share a complex relationship with the environment unlikely captured by traditional economic valuation methods. Supporting this point, Adger et al. (2011) observe that climate change policy tends to disregard the relationship between aggregate measures of human welfare and the environment, that is, the "emotional, symbolic, spiritual, and widely perceived intrinsic values of the environment."

The main focus of this paper explores the complex relationship between people and the environment. In particular, it seeks to address the various trade-offs between conservation and development, and the common undervaluation of natural resources within conventional decision-making frameworks. Building on the literature on dual-discounting, this study suggests an approach for determining the discount rate for environmental assets in the case of land-use planning – the so-called Equivalency Principle (EP). This is based on the normative proposal explained in Chiabai et al. (2013), which argue that when one of two identical pieces of natural land located in the same administrative unit has been granted permission for development, market distortions stemming from regulations and externalities arise that will cause these two lands to be valued differently. This situation generates an anomaly that potentially may have deep ethical and environmental implications, as it may generate incentives to urbanise natural land rather than to use or restore existing urban land. The authors propose that both pieces of land should be valued equally, as the present value of both is at least equivalent, and subsequently, future generations are likely to give them equal utility and economic value. An important benefit of this approach is that it avoids making assumptions about the expected welfare or growth rate of consumption of future generations, and the magnitude of projected uncertain impacts for example due to climate change, which might materialise differently in the future.

Based on the EP, this paper estimates discount rates for several types of natural assets across Europe, based on the hypothesis that rates are likely to differ geographically, reflecting the preferences of the society where the land or natural resource is located. The objective of this study is thus to develop the EP as a practical rule of thumb that could guide investment decisions in the context of environmental and resource economics, and help to justify the use of lower-than-market discount rates for valuing environmental assets and ensuring sustainable land-use planning on both ethical and economic grounds.

The rest of the paper is organised as follows: Section 2 first discusses the theoretical basis of the EP including its economic rationale and caveats, followed by an explanation of the methodological approach applied in this study Section 3 presents the results for over 300 sites across Europe. Section 4 discusses some of the main findings and section 5 is devoted to conclusions.

2. Method

2.1. Foundations of the EP

As discussed previously, dual discounting can be used by Governments and donor agencies (e.g. financial institutions) as an additional policy instrument for environmental protection. In an ideal scenario, this would imply using market rates for projects that do not affect the environment but lower rates, such as those derived from the EP, for projects that do. This is justified on the basis that it is reasonable to expect a higher level of scarcity of natural resources in the future and investments to preserve such assets today need to take account of this. Of course, threats to the environment, i.e. encroaching development in natural areas to sustain economic growth and potentially catastrophic impacts due to future climate change, may deplete environmental resources to such an extent that damages become irreversible. Moreover, while the exact relationship between the discount rate and the exploitation of natural resources is unknown, the general consensus is that the higher the discount rate, "the faster the depletion of exhaustible resources and the more intense the harvesting of renewable resources in the future" (Markandya and Pearce, 1991, p. 148). The EP offers one way of addressing this by estimating a range of discount rates that can be used in cost-benefit analysis carried out for investment projects affecting natural land.

Let us now, for illustrative purposes, imagine two plots of natural land located in the same area, N_1 and N_2, which have identical environmental and geographical characteristics (slope, ecosystem, proximity to infrastructures, etc.). Having both the exact same characteristics today, the current value of both plots of land would be the same. If their characteristics do not change and both plots remain in a natural state in the long-term, then their utility is expected to be the same. However, if one of the plots is granted permission for development today then we can expect a significant increase in its market price, while the value of the natural land stays unchanged. Here, the administrative act of 'granting development' causes one of the lands to be valued higher, despite the inherent characteristics of both plots of land remaining the same. While some may argue that the added value reflects the expected stream of private benefits stemming from future development, the argument neglects the almost certain (and irreversible) loss of environmental externalities caused by such (or any type of) development. Moreover, the shift in land values increases the attractiveness of developing on the land valued lower, which means policy-makers are economically incentivised to urbanise natural land rather than to use or restore existing brownfields for development projects. As Loures and Vas (2018) postulate the process is further complicated by the numerous typologies and characteristics attributed to brownfields, which encompasses land types such as abandoned land, contaminated land, derelict land, underutilised land and vacant land. Without clear definition, different land types can likely be regarded as substitutable, without recognising the relative difference in intrinsic environmental benefits associated with each.

McCarthy (2002) asserts, brownfield reuse is fundamental for wider community goals aimed at achieving environmental protection, revitalising cities, and reducing suburban sprawl. Such distortions in the market must be addressed if we are to ensure the sustainable protection of vital environmental assets and services, particularly given the already impending challenges of climate change for future generations. The solution offered by Chiabai et al. (2013) suggests that discounting may be used to regain the equivalency in the present value of both plots of land. This is done by equating the discounted sum of the flow of benefits of the natural land with the current market price of the development land, regardless of whether it has been designated for natural, residential or industrial purposes. The objective of this approach is not to derive relative values for the purpose of valuing natural land, but rather it specifically chooses to focus on the discount rate as a practical tool for informing land-use decision-making in cases involving the environment. In fact, the main strength of the approach stems from the idea that policy-makers can easily integrate its concept into cost-benefit appraisals for investment projects irrespective of time, scale or contextual setting. In fact, policy makers often have serious difficulties to choose the discount factor or this is given by financial authorities with no environmental or ethical consideration involved.

In practical terms, if plot N_1 is zoned as urban (U), either for residential or industrial use, then N_1 = U; while N_2 remains in its original state (N) (Figure 1). Here, the market price of the development land becomes greater than that of the natural plot of land ($P_{N1} = P_U > P_{N2}$). The value of N_2, usually estimated as the present value per hectare (PV_N), is often determined by non-market valuation methods, and should represent the Total Economic Value (TEV) of the natural land, comprising both use and non-use values. Using the conventional equation for the present value, the EP can be expressed as follows:

$$PV_N = \sum_{t=1}^{T} \frac{{V_N}^t}{(1+d)^t} = P_U \qquad (1)$$

Where PV_N is the TEV of the natural land; V_N is the flow of benefits of the natural land in time t; d is the discount rate; and P_U is the price per hectare of the development land. When time extends to perpetuity the formula can be simplified to the following expression (Mills and Hamilton, 1994):

$$PV_N = \frac{V_N}{d} = P_U \qquad (2)$$

[Figure 1 here]

We can justify extending time to infinity on the basis that human welfare depends on the quality of ecosystem services and, because of this, their total value for the economy and for human society may be infinite (Costanza et al., 1997). While the above formula assumes that the benefits are constant over time, flows can be expected to increase over time in real terms as a result of growing real incomes and increasing scarcity of services from natural capital (Krutilla, 1967). In this case the value of N for a finite timescale would be:

$$PV_N = \sum_{t=1}^{T} \frac{V_N(1+g)^t}{(1+d)^t} \qquad (1')$$

Where g stands for the growth rate or appreciation of benefits of natural land over time. This can also be expressed as:

$$PV_N = \sum_{t=1}^{T} \frac{V_N(1+g)^t}{(1+d)^t} \approx \sum_{t=1}^{T} \frac{V_N}{(1+d-g)^t} \qquad (1'')$$

When time extends to infinity the formula can be simplified to the following expression:

$$PV_N = \frac{V_N}{(d-g)} = P_U \qquad (2')$$

Solving for Equation 2' we can obtain the discount rate that equalises the values of both lands:

$$d = \frac{V_N}{P_U} + g \qquad (3)$$

Equation 3 is based on the consideration of increasing flows of benefits over time. If growth is not taken into account, g would equate to zero.

Alternative policy instruments for achieving environmental protection can often be classified into two main approaches: "command and control" and "market-based" methods. While the first approach, command and control, relies on various (ambient, emission and technology) standards to promote socially desirable behavior

(Field and Field, 1997), market-based approaches instead aim to incentivize firms (e.g. through taxes and pollution rights) to make more sustainable choices. Both policy instruments face a number of political economy issues however. For example: conventional command and control approaches have often been criticized for not meeting environmental objectives at least-cost, while various political and technological constraints make market-based approaches ill-suited for dealing with certain environmental problems (Berck, 2018). In cases where traditional policy instruments are unable to effectively meet environmental objectives, such as the land planning example described before, the EP offers an alternative approach for enhancing environmental protection. Contrary to implementing a new environmental tax or passing additional legislation, which are highly political processes that may take years to carry out, one of the main advantages of the EP is that policy makers can use it as a basis for determining environmental discount rates immediately and its application is theoretically valid under only two assumptions:

1. Past decision making by the administrative unit[i] of reference on development versus protection of natural assets has been *close to* socially optimal, so that the marginal present value of the natural land is equal to the marginal present value of the adjacent development land (Chiabai et al., 2013), and;
2. Future generations may be affected in the long run by decisions made over the land under consideration

However, while optimal decision-making would imply policy-makers are making perfect marginal trade-offs between preservation and development, the assumption here is that (while all else is optimal)[a] land-use decisions have not been able to properly account for the myriad of environmental externalities associated with natural lands. This can be the case very often in decisions related to land use planning. Indeed, as Chee (2004, p. 549) posits: 'decisions concerning ecosystem management are often complex, socially contentious and fraught with uncertainty.' This relates, for example, to difficulties in realizing the full range of implicit regulating, provisioning, cultural and supporting ecosystem services of the environment; in capturing the true 'market' value of complex environmental functions (e.g. aesthetic and cultural worth) where no market exists, and; in appropriately determining the welfare that environmental preservation would bring to future generations

[a] i.e. in terms of legality, cost-efficiency, feasibility etc.

greater affected by climate change. Failure to internalize environmental externalities within land-use decision-making has meant local governments have fewer policy levers to disincentivise development through mandatory or voluntary regulations, with zoning remaining the most widely accepted control tool for land-use planning (Geoghegan, 2002).

Figure 2 illustrates the concept of near-optimal decision-making using a stylized production possibility frontier (PPF). The figure is divided into three areas (A, B and C):

- Area A – represents a situation where decision-making has been close to optimal. Therefore, the marginal benefit of developing an additional unit of nature is approximately the same as the cost. This is the only area where the EP explicitly applies.
- Area B - when an area has been over-developed the EP should not be used as protecting the remaining natural land will far outweigh the benefits of further development. This can be seen when moving from point B_1 to B_2, where a small gain in development causes a great loss in environmental benefits.
- Area C – the reverse scenario is also possible. In regions that are severely under-developed, the cost to society from the loss of some environmental services will be far outweighed by the benefits that development will bring. This is illustrated by a shift from point C_1 to C_2.

The second assumption required to justify the use of the EP is that future generations are affected in the long run by decisions taken on the land. This assumption is easy to meet as natural land that has been degraded or converted can rarely be restored to its original state (Moreno-Mateos et al., 2017, 2015). This irreversibility highlights the importance of using the EP in decision-making in order to preserve the remaining natural land for future generations by incentivizing the use of brownfields for new construction instead of developing on natural parcels of land.

[Figure 2 here]

2.2. Methodological approach

In order to satisfy the pre-conditions of the EP, two types of data were collected; the first representing the non-market values of natural land, and the second representing the prices of neighbouring lands with similar environmental characteristics designated for a certain type of development (i.e. commercial, industrial, residential) within the same administrative unit. Data was collected from sites across Europe[ii] in order to assess how the application of the EP would change according to different contextual settings and a sensitivity analysis was conducted to better understand the ranges of discount rates observed. For the purposes of presenting an illustrative example of how the EP might apply, and to better understand the drivers of differences in values, a simplified approach was adopted that does not consider the impact of various economic growth rates in the future. This was intended to eliminate the inherent uncertainty in such values.

2.2.1. Data collection

The first stage of the methodology involved collecting data on the values of natural land. This involved conducting an extensive literature review of both the scientific and grey literature, using widely recognised search engines such as Google Scholar and Web of Science. A keyword search was performed to detect primary valuation studies that measured the TEV of natural land. The TEV is defined as "the sum of the values of all service flows that natural capital generates both now and in the future – appropriately discounted" (Kumar, 2012, p. 188) and encompasses: direct and indirect use values, option values, existence values and bequest values. Because of difficulties in capturing and accounting for all components of TEV (Anderson et al., 2016), as well as the conceptual and empirical difficulties involved in adding up various component values of TEV (Randall, 1987), studies that included at least one component of TEV were included. Both direct (stated-preference) and indirect (revealed preference) approaches were included to limit the potential bias associated with considering one approach, as well as to demonstrate the flexibility of the EP. Due to the large volume of research conducted in earlier years, a time-range between 1990 and 2015 was chosen. All values were converted to EUR 2016 prices using the Purchasing Power Parity (PPP) and Consumer Price Index (CPI) conversion factors provided by the Organisation for Economic Co-operation and Development (OECD)[iii].

After the initial stage was complete, the next stage involved collecting data on neighbouring lands designated for development purposes. At the aggregate level, Eurostat is currently the only public database available that provides land prices at the EU and national level. These values focus predominantly however, on agricultural land types, and lack the geographical detail for analysis at the district or provincial scale. Other sources, including national government agencies and national statistical offices were searched, some of which focused exclusively on agricultural land types and lacked data on prices for alternative land uses. Most official sources however, such as the Valuation Office Agency (VOA) in the UK, the Federal Statistical Office in Germany, the Spanish Ministry of Public Works and Transport in Spain, the Belgian Statistical Office in Belgium, the Central Statistical Office of Poland and the National Land Survey of Finland, provided relevant data on land markets, including data on prices for building land, such as residential and commercial land. For the remaining countries, publicly available regional real-estate market reports were used to gather data on prices of land designated for particular development purposes.

The literature on natural land values and the data on prices of adjacent development lands were sorted and categorised within a database. Studies with missing information or that were located in regions with no data on land prices were excluded from the database. The final database consisted of 47 studies and 308 site values, across 11 European countries. A summary of the literature on the values of natural land can be seen in Table 1, and relative data on market prices of development land can be found in Appendix I.

[Table 1 here]

2.2.2. Data description

Considering the availability of data on natural land values and market prices of development lands, the largest estimated range of discount rates was calculated for the United Kingdom with a total of 90 values, followed by the Netherlands and Greece, with 64 and 48 values, respectively (Fig. 3). Over 70% of entries employed the use of stated preference methods, such as the Contingent Valuation Method (CVM) to value natural site benefits. Although such methods have been subject to certain controversies and potential biases (Diamond and Hausman, 1994), the large share of studies adopting this approach is reflective of the fact that stated preference methods are often the only available tool to value certain sites or to elicit certain types of values. In addition, despite their limitations, such approaches for ecosystem service valuation can provide important insight for decision-making where no alternative exists. Indeed as Bingham et al. (1995, p. 87) assert, while improving economic valuation of ecosystem services may lead to improved decision-making over environmental issues, it will not solve for the "collective political decisions about distribution issues, including rights to resource use to future generations or within the present generation."

[Figure 3 here]

Studies included a range of provisioning, supporting, regulating and cultural ecosystem services (Table 2), which are defined as the benefits that humans obtain from ecosystems produced by interactions within the ecosystem (Assessment, 2005). Most common were provisioning services such as fresh water provision and the supply of raw materials, as well as cultural services such as tourism, or the recreational or aesthetic value of the land. Other services included flood and erosion control, and carbon sequestration (regulating services), as well as biodiversity and nature conservation (supporting services). Habitat types also varied across studies, with most values estimated for forests (137), followed by wetlands (129), coastal areas (41), grasslands (30) and water bodies (15) (Figure 4). Table 2 presents general descriptions of methods, habitats, land status, and types of ecosystem services observed in the literature.

[Figure 4 here]

[Table 2 here]

3. Results

3.1. General results

A box plot showing the distribution of discount rates by habitat type is shown in Figure 5, and the median, mean, maximum and minimum result ranges are presented in Table 3. Average discount rates ranging between 0.3% and 1.1% were estimated across habitat types. Coastal areas represented the highest discount rates on average (1.1%), followed by wetlands (0.6%), grasslands (0.3%), forests (0.3%) and water bodies (0.3%). As figure 5 shows, excluding outliers[iv], the majority of discount rates across habitats fell below 1.2%, with median values ranging between 0% (in the case of water bodies) and 0.2% (in the case of wetlands). The higher discount rates for coastal areas is attributed to the generally higher social values placed on these habitats, with an average TEV of approximately €24,028 compared to €11,674, €6,603, €4,621 and €1,749 for wetlands, forests, grasslands, and water bodies, respectively. Certainly, these habitats tend to encompass a wide range of values, such as: biodiversity, nature conservation, aesthetic, recreation and tourism values.

[Figure 5 here]

[Table 3 here]

The discount rates observed by country are presented in Table 4. Average discount rates ranged between 0% and 3.8%, with an overall mean value of 0.6% across all countries. Overall, the majority of countries displayed average discount rates below 1%, with the exception of Germany, Poland and Spain, with rates of 1.4%, 3.8% and 1.7%, respectively. Maximum rates of 10.9% and 11% were found for sites in Spain and the UK, but with mean values of 0.7% and 1.7%, respectively, these were considered to be outliers. Indeed, the next highest discount rate was significantly lower, estimated at 6.8% in the case of Poland[v]. The high variation in development land prices for sites in Poland, ranging from €340,000 to €1,020,000 (Appendix I) can explain the difference of 4% found between the minimum and maximum discount rates for this country. Similarly, for the UK and Spain, the large variation in discount rates can be attributed to the large differences in natural land (Table 1) and development land values (Appendix I) for these countries.

[Table 4 here]

Across development sites, estimated discount rates ranged between 0.4% and 1.2%, with general development representing the highest rates on average, followed by industrial (0.9%), office (0.5%), residential (0.4%) and commercial (0.4%) land uses (Table 5)[vi].

[Table 5 here]

There has been much debate among economists as to whether the demand for environmental protection is disproportionately distributed across income groups. Indeed, conservation policies may be seen as regressive based on the notion that net benefits will be larger for individuals with high incomes than for those with lower incomes (Boardman et al., 2017). This is evidenced prominently in the case of contingent valuation studies, where a strong correlation is found between income and environmental protection. In such cases, individuals are often asked to value environmental resources based on conditions such as the welfare they derive from and their willingness-to-pay (WTP) for conservation programs. Consequently, a valid assumption would be that individual responses would depend largely on personal factors, such as the amount of disposable income available to them, and the proportion of which they are willing to allocate to environmental causes, as well as how much they value the environment relative to other non-environmental goods and services. For dealing with distributional issues across socio-economic groups, Pearce (2003) argues that both the income elasticity of demand and the income elasticity of WTP are useful measures for measuring the effect of income on levels of environmental protection and in classifying environmental goods. Where the former refers to the change in the *quantity* demanded of some environmental asset in response to a small change in income, the latter deals with the change in *WTP* for some environmental asset with changes in income. However, since the focus of most environmental policy is on public goods that have some quantity constraint, Pearce argues that the income elasticity of WTP is the more relevant measure of the relationship between income and the environment (Flores and Carson, 1997).

Since a large extent of the studies evaluated employed CVM studies to measure the value of natural land, and given the strong empirical relationship between income and environmental quality within CVM, a sensitivity analysis was conducted to test the relationship between various elasticities and the impact they might have on the EP and subsequent discount rates (see Appendix IV).

3.2. Hypothetical illustration of the EP in Spain

To show how the EP would work in practice, we present an illustrative case study where we imagine a development project is undergoing an investment appraisal. Using the data derived for Spain as an example, let us assume that a residential development project has been proposed for a natural site that has been estimated to generate annual environmental benefits (or a TEV) of €22,309 per hectare. Given that the development will likely eradicate most (if not all) of the natural benefits of the land, we can use this figure as a proxy for the environmental (social) cost of development. Now let us imagine that for the same plot of land the developers foresee a positive net economic impact of €40,000 annually. The local authorities must now make a decision over whether the development goes ahead or not. In order to make their decision, they wish to consider the net impacts of the project over the next 40 years. This requires comparing the social cost of building on the land with the expected stream of economic benefits generated by the project. By simply comparing the project's costs and benefits, we can examine the impact that different discount rates would have on the final outcome of the decision. While the economic benefits are discounted using a market-based rate of 6%[b], we consider three scenarios for discounting the social cost of the project: the first uses the same market-based rate of 6%, the second applies a rate of 4% as suggested by Gollier (2008), and the last uses the discount rate determined by the EP[c] (Table 6).

[Table 6 here]

The results of the hypothetical cost-benefit analysis presented in Table 6 show us that the investment project would generate a positive net impact over 40 years of €177,993 and €283,880 when applying discount rates of 4% and 6%, respectively. However, when using the 1.39% discount rate derived from the EP, the project is shown to result in a negative net-present value of -€61,467. Thus, the project would only be justified under the first two scenarios. This demonstrates how the discount rates applied in traditional cost-benefit analyses can be largely biased (Chiabai et al., 2013), while a more sustainable approach would be to use site-specific discount rates (such as those from the EP) to ensure that affected environmental assets are being properly accounted for. The reason being that, *ceteris paribus,* in countries where the environment is highly valued rates could be higher than in those where the environment is valued less, and in countries where market prices of development land are high, we can expect to find lower discount rates than in countries where the market price for development land is low.

4. Discussion

[b] This estimate is in line with the ADB, which reports a social discount range of 4-6% for various sectors in Spain (Zhuang et al., 2007)

[c] This is estimated using the conventional formula for the EP, calculated based on a natural land value of €22,308.67 and a development land price of €1,605,229 situated in Valencia, Spain

The application of the EP could represent an interesting instrument to re-establish the equivalency between the economic importance of two types of land (natural land and natural land designated for development) accounting for all attributes. In practical terms, this means that the discount rate derived from the EP can favour the protection of natural land in investment projects concerning development choices over the territory. This is because current assessment methods are unable to properly account for the total value of natural assets and environmental resources, particularly those that have no close monetary substitutes (Dietz et al., 2016). As a result, management regimes rarely consider the aggregate measures of human welfare, such as cultural or psychological values and the irreversible loss of nature, which are of at least equal, if not growing importance (Adger et al., 2011). The EP therefore reinforces the idea that discount rates should differ geographically on the basis of local specificities, including the preferences of society on development, environmental policies and environmental resources. That is, in countries where great value is already given to natural land or environmental resources there is less of a need to adjust discount rates to guarantee their protection. In contrast, in areas where little value is given to natural resources, the EP can be used as an additional policy instrument to ensure protection by using lower discount rates during project appraisal.

Our results show that factors such as the type of habitat, geographical location and the type of land-use development can play a role in shaping discount rates derived by the EP. In the case of the latter, for example, discount rates were estimated to be lower for residential land use (0%) when compared to industrial land use (1%) across study sites (Table 5). This shows that the magnitude of the discount rate depends on both the TEV and the market price for development land. As mentioned previously, this implies that the higher the price of development land, the greater the need to use discounting to generate the right incentives to protect natural land. And equivalently, the lower the value attached to the natural environment, the greater the need to ensure its protection through appropriate discount rates. Certainly, with average discount rates below 1% for most countries (Table 4), the main findings indicate a support for policy decision-making that sustains the protection of natural lands and ecosystems. By essentially equating the long-term value of protection and the cost of development on natural lands through locally specific discount rates, the EP provides an alternative means of assessing the financial viability of projects and programmes that could detrimentally impact conservation efforts and sustainable landuse practices.

Taking the case of climate adaptation for example, the EP can be an important determinant for deciding between adaptation options that may have fundamentally different impacts on the use of natural resources. This is an important consideration since decisions taken on adaptation today may have negative environmental and social implications for future generations, and since the value of future generations is often only considered in todays decisions through formal discounting methods in economics (Adger et al., 2009). This raises concerns as to how we can reconcile the non-market and non-instrumental aspects of the environment with the economic metrics employed in climate change decision-making, as well as how to deal with the risk of irreversible loss. Indeed, while economic losses are easily accounted for in conventional decision-making frameworks on climate change, ecological, cultural and psychological losses are often, if not always, underemphasized (Adger et al., 2011). This is demonstrated within this analysis by the high frequency of discount rates estimated to range between 0% and 1%, suggesting that natural sites are commonly being undervalued (Appendix III). Policy development must therefore recognise that successful adaptation is not limited to the efficiency of economics or engineering, but depends equally, if not more, on the wider societal and environmental benefits of measures. Subsequently, as Adger et al. (2011, p. 20) note: “there is a need for more geographically and culturally nuanced risk appraisals that allow policy-makers to recognise the diverse array of climate risks to places and cultures as well as to countries and economies.”

Certainly, application of the EP and the analysis presented here maintains both benefits and limitations. Of noteworthy, one important ancillary benefit of applying the EP relates to the uncertainty of expressing TEV as a unit per hectare. While the use of common units of measurment is crucial in economic valuation for comparative purposes, uncertainty lies in calculating a flow value by simply dividing the total value of an entire site by its area. Indeed, much of this is related to identified cognitive biases such as scope insensitivity in CVM (Kahneman, 2000). As a result, values per hectare may be lower for larger sites, and higher for smaller sites, while the total TEV may be similar in magnitude. In some cases this may lead to unrealistic values of natural land, as the true value per hectare may not be appropriately reflected. This phenomenon has been widely recognised in welfare economics, where the overall size of a natural site may affect is value per unit area, in accordance with the concept of decreasing marginal utility. The notion is supported by several meta-analyses of ecosystem and non-market valuation. Ghermandi et al. (2010) in their extensive valuation of natural and man-made wetlands, for example, find a negative relationship between wetland abundance and wetland value. The authors attribute this to a substitution effect, whereby people's perceptions and preferences of one site are affected by the presence of alternative sites that may substitute some of the social and environmental services provided by that environment. Similarly, in their study on biodiversity values in forest ecosystems, Ojea et al. (2010) find that the provision of additional forest hectares results in a significant marginal decreasing utility, where a 1% increase in forest area leads to a 0.59% decrease in forest marginal value. The hypothesis is also supported by Schild et al. (2018), in their meta-analysis on the monetary valuation of dryland ecosystem services the authors find that the larger the selected study extent, the lower the resulting estimated ecosystem service.

The application of the EP may offer a solution to these problems, since the value per hectare of these ecosystems may be lower than might otherwise be expected from an ecological perspective, the associated discount rate will also be smaller, allowing for a re-balance in the value of the natural site compared with its development counterpart. This can be justified from a biological and ecological standpoint also, since rigorous economic assessment would require us to adress issues related to non-linearity, threshold effects, spatial variability and irreversible damages (Bagstad et al., 2014).

The main limitation of this study relates instead to the availability of market data on development lands. While for most cases data on adjacent development lands within similar district or provincial jurisdictions was available, for some countries market prices for development land were found only for specific urban areas or capital cities. This can be problematic since the EP should ideally be applied using land values with similar environmental characteristics and within the same local jurisdiction. Moreover, land prices from capital cities will probably be among the highest within each country, which will subsequently lead to lower discount rates than we might otherwise expect. For example, in the case of Sweden, TEV values of €4-20/ha/year (Table 1) were obtained from an assessment of ecosystem services in the County of Vasterbotten, while prices for residential and industrial land were representative of Stockholm. As a result of the generally low TEV values of the natural sites and the high market prices for development land in the capital, discount rates for Sweden were estimated at 0.0% on average (Table 4).

Nevertheless, the discount rates presented here are not intended to be prescriptive. Instead, the purpose of this study is to show how the EP might apply in different societal and contextual settings. Accounting for the strong heterogeneity of the data related to land-use, scale and representativeness of sites for each country would help consolidate results to some degree, however undertaking a serious comparison among countries would rely on more robust site-specific information on the market prices of land designated for development, social preferences about natural sites, as well as decision-making affecting territorial planning. Indeed, these factors have strong geographical implications that will vary among and within each country, and will mean that discount rates can be expected to differ considerably according to each site. The key contribution of this work is therefore to show that the EP can be employed in completely different contexts, moving towards the definition of different "*Equivalency Principles*".

5. Conclusion

With discount rates ranging between 0% and 11%, and averaging 1% across countries, the EP has been demonstrated as an alternative policy tool for incentivising the protection of natural lands within territorial planning and decision-making. In line with our aforementioned hypothesis, the EP results in discount rates that are geographically differentiated and that vary according to habitat and social preferences over natural and development land types. Consequently, the EP offers a new way of guaranteeing sustainable land-use in the long-term, taking into account the many dimensions of sustainable development, including: economics, society, institutions and the environment. Moreover, the EP can provide an important, and often unconsidered, dimension to decision-making particularly in the case of climate change where the threat of catastrophic impacts and environmental degradation may cause irreversible damages in the future. Subsequently, the EP may be used within policy development, particularly in land and urban planning decision-making contexts, for addressing increasing scarcity of natural resources, by balancing economic and environmental objectives, and capturing a more considered value of natural resources and their intrinsic worth to both current and future generations. The EP is particularly relevant for adaptation decision-making, which has been largely structured by economic objectives set forth by institutions and political processes without recognising the wider cultural and context-specific ramifications of policy choices. Further research in this area would benefit from a more in-depth insight into social preferences over natural sites as well as locally-specific factors affecting sustainable land-use practices and decision-making, which will improve the theoretical and practical underpinnings of the principle.

Acknowledgements: This research is supported by the Basque Government through the BERC 2018-2021 program and by the Spanish Ministry of Economy and Competitiveness MINECO through María de Maeztu excellence accreditation MDM-2017-0714. Additionally, it is also supported by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 603906 (ECONADAPT Project) and the Horizon 2020 RESIN Project (EC-H2020, grant agreement no. 653522). E. Sainz de Murieta is also grateful for the support received from the Basque Government (grant no. POS_2016_1_0089

491 # Appendices

492 ## Appendix I

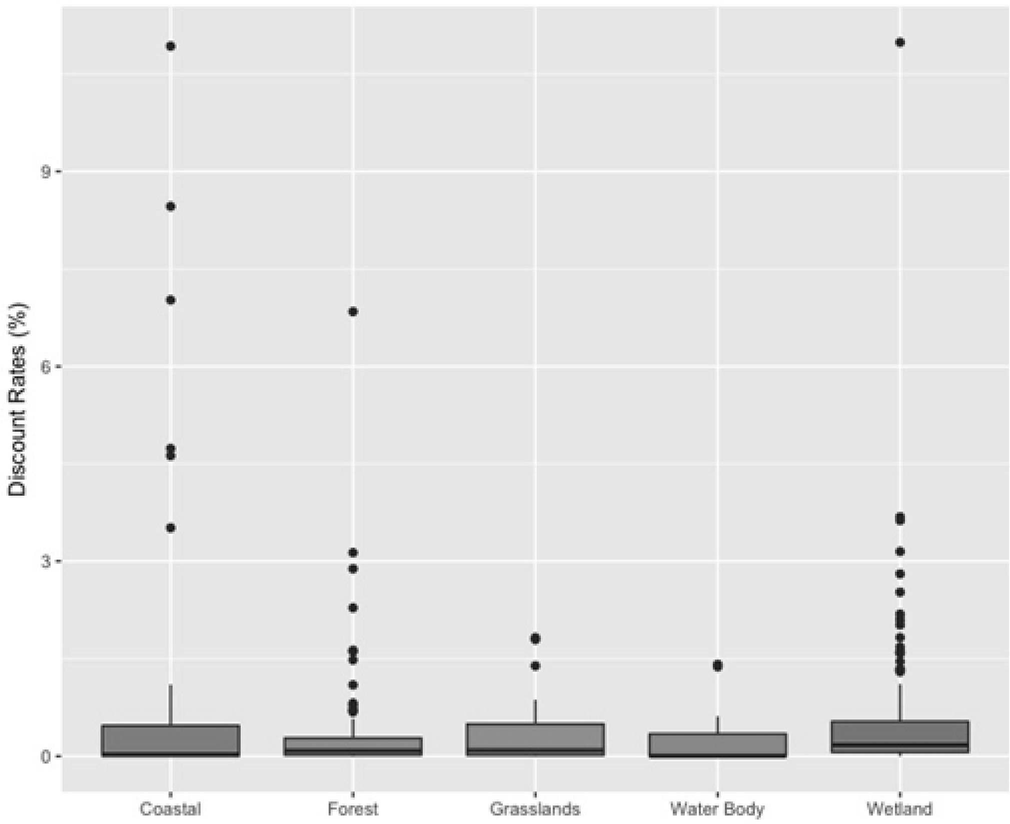
493 **Description of market prices for general development, residential, industrial, office and commercial lands**

Country	Price of Development Land (EUR, 2016)	Type	Source(s)
Belgium	943,893 – 1,473,394	General Development (Building Land)	(Statistics Belgium, 2015)
Finland	320,000 – 1,675,000	Residential, Industrial, Commercial	(National Land Survey of Finland, 2016)
Germany	1,135,084	General Development	(Statistisches Bundesamt, 2015)
Greece	1,160,503 – 26,111,326	Commercial, Industrial & Residential	(NAI, 2011)
Italy	99,907 – 1,651,263	Commercial & Industrial	Average of advertised plots for sale on real estate sites in the region
Netherlands	1,018,605 -239,372,093	Commercial, Industrial, Office, Residential	(NAI, 2011)
Poland	340,278 – 1,020,835	Residential, Industrial, Commercial, General Development	(Central Statistical Office, 2016)
Spain	894,112 – 2,366,317	General Development & Industrial	(Ministerio de Fomento, 2014)
Sweden	4,257,956	Residential	(NAI, 2011)

Turkey	3,142,829	Industrial	(Colliers International, 2016)
UK	991,991 -4,668,192	Residential & Industrial	(Valuation Office Agency, 2011)

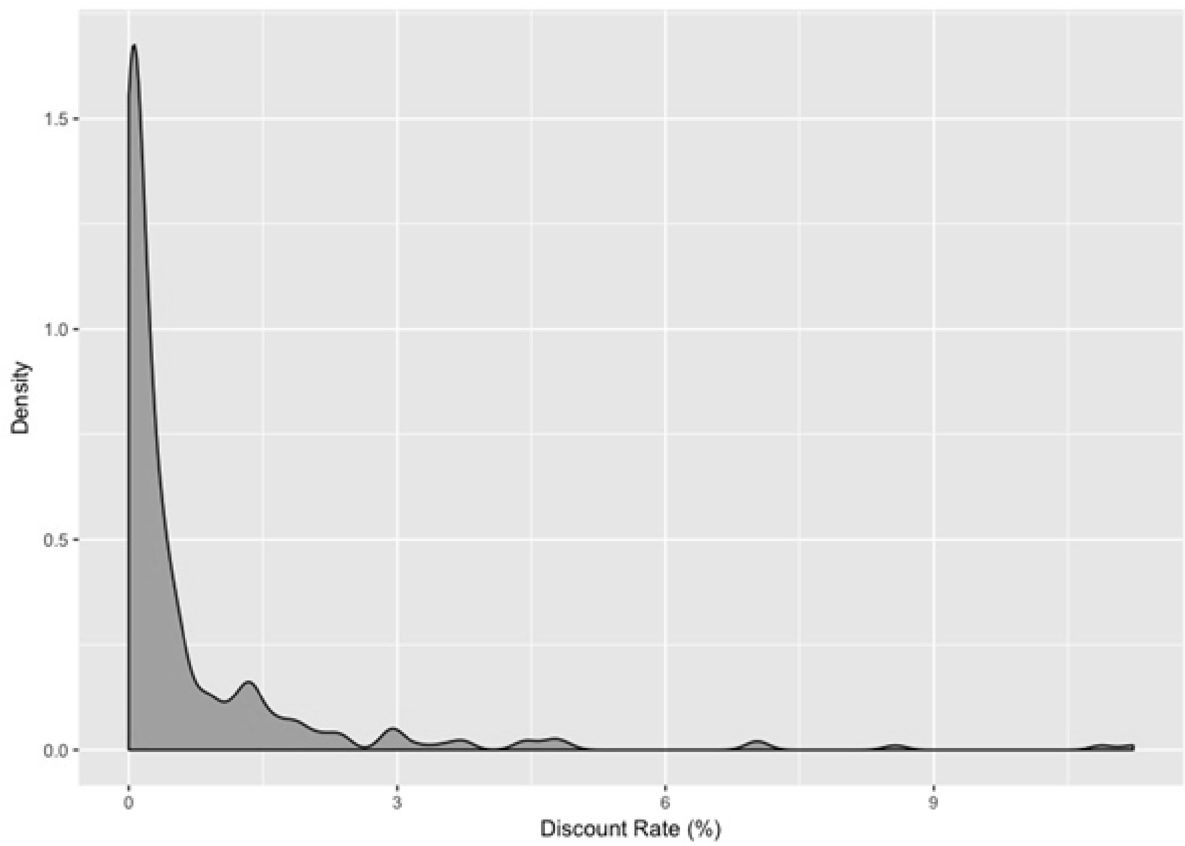
Appendix II

Box plot showing estimated discount rates by habitat type (including outliers):



Appendix III

Density curve showing frequency of discount ranges observed



Appendix IV

Based on a comprehensive literature search, estimates for the income elasticity of WTP were often found to be less than unity, and commonly ranged between 0.3 and 0.7 (Pearce, 2003). However this range is challenged by McFadden & Leonard (1993) and McFadden (1994), based on their assertion that an income elasticity of WTP that is less than unity does not accord with economic intuition, based on the plausibility that preservation would be a “luxury” good that for poor households is replaced by needs for food and shelter. Based on these arguments, elasticities of 0.3, 0.7, 1.0 and 1.2 were chosen to test how discount rates change as the income elasticity of WTP changes. On the grounds that an elasticity of 0.3 will mean that a 1% change in income will result in a 0.3% change in WTP, and conversely, that an elasticity of 1.2 will mean that the same 1% change in income will result in a 1.2% change in WTP, and so on and so forth. These results are included in the online supplemental material. In general, the EP was found to be insensitive to changes in elasticity**.** That is, for a 1% change in the value of the elasticity the discount rates vary between a minimum of 0.06% to a maximum of 0.43%. More closely, it is possible to see that for countries such as Finland and the UK, the higher the income elasticity of WTP the higher the discount rate resulting from the EP will be. That is, the more sensible the WTP to changes in income, the less you need to use the discount rate to adjust the values of the two plots (i.e. the higher the recommended discount rate is). However, in countries such as Spain and Greece this most frequently works in the opposite direction. This may suggest that demand for natural and well preserved land in richer countries is considered a normal good (i.e. income elasticity of demand being positive) while in countries with lower GDP that have been recently suffering a severe economic crisis may be seen as an inferior good (i.e. income elasticity of demand being negative). Answering this question is however well beyond the scope of this paper and may well represent a challenging research question worth exploring in detail.

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Figures:

Figure 1: Two pieces of natural land (N1, N2) of equal properties selected to illustrate the application of the EP

Figure 2: Conditions of socially optimal decision-making on land-use allocation

Figure 3: Number of discount rates estimated for each country

Figure 4: Distribution of habitat types by country

Figure 5: Box plot showing discount rates by habitat type

Tables:

Country	Habitat(s)	Land area (ha)	Value ha/yr (EUR, 2016)	Source
Belgium	Fresh & saltwater coastal areas; forest	540 - 2,500	1,505 – 6,779	(Desmyttere and Dries, 2002; Moons, 2002; ten Brink et al., 2011)
Finland	Forest	20,000	426 - 495	(Kniivilä et al., 2002; ten Brink et al., 2011)
Germany	Wetlands	15,000	12,048 – 20,712	(Meyerhoff and Dehnhardt, 2007)
Greece	Wetlands, water body, forests, grassland, coastal	11,400 – 146,680	9 – 36,514	(Birol et al., 2006; Ghermandi et al., 2010; Pavlikakis and Tsihrintzis, 2006)
Italy	Grassland, coastal, forest	3,000 - 5,500	2 – 5,750	(Bellù and Cistulli, 1997; Marzetti et al., 2011; Zoppi, 2007)
Netherlands	Forest, grassland, water body	5,200 - 5,500	1,364 – 14,127	(Hein, 2011; Kuik et al., 2006; ten Brink et al., 2011)
Poland	Forest	32,764	23,290	(Považan et al., 2014)
Spain	Water body, grassland, coastal, forest, wetlands	117 - 5,550,000	6 – 258,527	(del Saz-Salazar and Rausell-Köster, 2008; Galarraga et al., 2004; Hoyos et al., 2007; Mogas et al., 2006; Ramajo-Hernández and

				del Saz-Salazar, 2012; ten Brink et al., 2011)
Sweden	Forest	3,717,407	4 -20	(Bostedt and Mattsson, 2006)
Turkey	Wetlands	14,750	387	(Gürlük, 2010)
UK	Wetlands, grassland, water body, coastal, woodland, mountain, forest	67 -179,284	9 – 94,860	(Bateman et al., 2000; Bishop, 1992; Cobbing and Slee, 1994; Everard, 2009; Hanley and Spash, 1993; Klein and Bateman, 1998; Luisetti et al., 2011; Maxwell, 1994; ten Brink et al., 2011; Turner et al., 2004; Willis, 1996, 1990; Willis and Garrod, 1993)

Table 1. Description of natural land studies observed in the literature

	Typology	Description
Habitats	Forests	Boreal, coniferous, deciduous, forested swamps, woodland
	Wetlands	Floodplains, rivers, lakes, lagoons, marshes, mud flats, swamps
	Grassland	Farmland, meadows
	Coastal	Shoreline, coastline, dunes
	Mountain areas	Basins, cols, inland hills, valleys
	Green urban areas	Parks, green land, greenbelt
Ecosystem services	Provisioning	Freshwater provision, timber, wood fuel, agriculture, forestry, fisheries
	Regulating	Erosion and flood control, carbon sequestration, water purification and regulation, wind protection
	Cultural Services	Recreation, tourism, cultural and historical heritage, eco-tourism, education
	Supporting Services	Nutrient cycling, habitat and biodiversity creation and conservation
Valuation methods	Contingent Valuation (CVM)	
	Choice Experiments (CE)	
	Benefit/ Value Transfer	
	Cost-based Approaches	
	Travel Cost Method (TCM)	
	Hedonic Pricing	
Status of land	Protected	National Parks, Nature Reserves, Sites of Special Scientific Interest, Sites of Community importance, Ramsar and UNESCO sites, Environmentally Sensitive Areas.
	Unprotected	Urban parks, green land, agricultural land

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Typology	Description

Table 2: Description of habitats, ecosystem services, valuation methods and status' of natural lands

	Coastal	Forest	Grassland	Water Body	Wetland
Median	0.0	0.1	0.1	0.0	0.2
Mean	1.1	0.4	0.3	0.3	0.6
Max	10.9	6.8	1.8	1.4	11.0
Min	0.0	0.0	0.0	0.0	0.0
No. Of Entries	**41**	**137**	**30**	**15**	**129**

Table 3: Estimated discount rates by habitat type (%)

Country	No. Of Entries	Median	Mean	Max	Min
Belgium	4	0.2	0.2	0.3	0.1
Finland	44	0.5	0.9	4.5	0.0
Germany	2	1.4	1.4	1.8	1.1
Greece	48	0.1	0.4	3.1	0.0
Italy	21	0.0	0.0	0.3	0.0
Netherlands	64	0.1	0.2	1.3	0.0
Poland	4	3.0	3.8	6.8	2.3
Spain	26	0.1	1.7	10.9 (8.5)*	0.0
Sweden	4	0.0	0.0	0.0	0.0
Turkey	1	0.0	0.0	0.0	0.0
UK	90	0.3	0.7	11.0 (3.7)*	0.0
Total	**352**	**0.2****	**0.6****	**11.0****	**0.0****

*() values in parenthesis indicate next highest value

** represents the average value across all cases

Table 4: Estimated discount rates by country (%)

	General	Commercial	Industrial	Office	Residential

	Development				
Median	0.1	0.1	0.3	0.2	0.1
Mean	1.2	0.4	0.9	0.5	0.4
Max	10.9	2.9	11.0	4.1	4.5
Min	0.0	0.0	0.0	0.0	0.0
No. Of Entries	42	47	88	27	104

Table 5: Estimated discount rates by development type (%)

A. Benefits of the project		**B. Environmental costs**		**Net Present Value (A-B)**
Discount rate applied to project benefits (%)	Present value of project benefits	Discount rate applied to environmental costs (%)	Present value of environmental costs	
		6%	357,971.54	283,880.33
6%	641,851.87	4%	463,859.13	177,992.74
		1.39%	703,318.67	-61,466.80

Table 6: Cost-benefit analysis example of a hypothetical investment project in Spain using a time horizon of 40 years. All estimates are in EUR (2016)

Endnotes:

[i] Chiabai et al. (2013, p. 540) define administrative unit as "the public administration having the responsibility for land use planning and for granting building permits in a specified area".

[ii] All observations come from Europe except one from Turkey, but for simplicity we will refer to all countries as European

[iii] Database on OECD PPP and CPI factors can be found at: http://stats.oecd.org

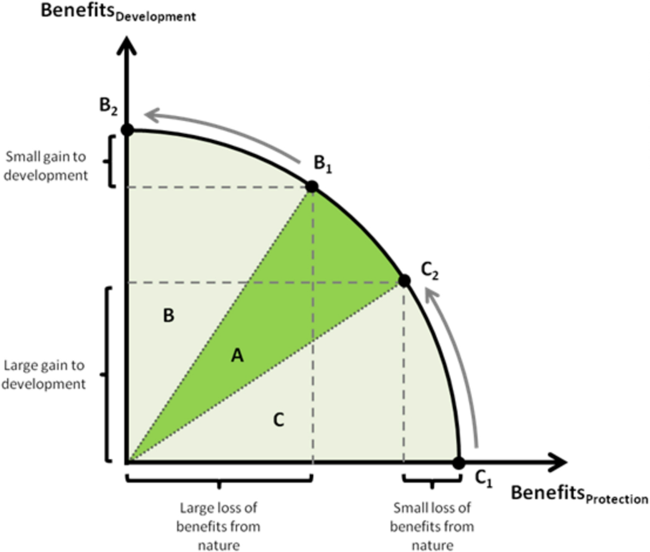
[iv] See Appendix II for box plot of discount ranges by habitat type including outliers

[v] As represented in Figure 4, the value of 6.8% is also considered to be an outlier, and may be an overestimation of the maximum discount rate for this country.

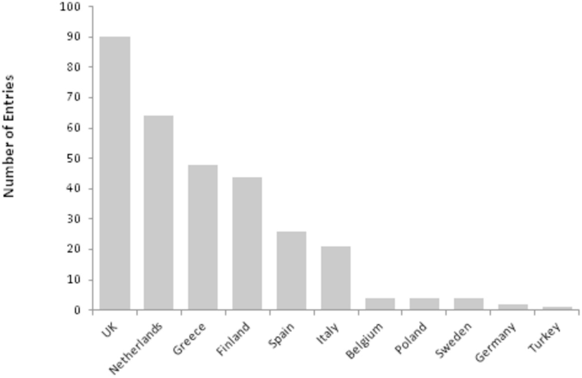
Highlights:

- The Equivalency Principle tends to result in lower discount rates than market rates
- Rates based on the EP were estimated for 11 European countries
- Results support the premise of geographically differentiated discount rates
- Results show rates ranging from 0% and 11% across all European countries
- An average discount rate of 1% across study sites was estimated


N1
N2
MUSKIZ
CEMENTERIO
RO/ POBEÑA
271
273
238
239
241
244
245
269
270
235
Escala: 1.000
ETRS89 30N X : 489.996,10 Y : 4.799.150,80

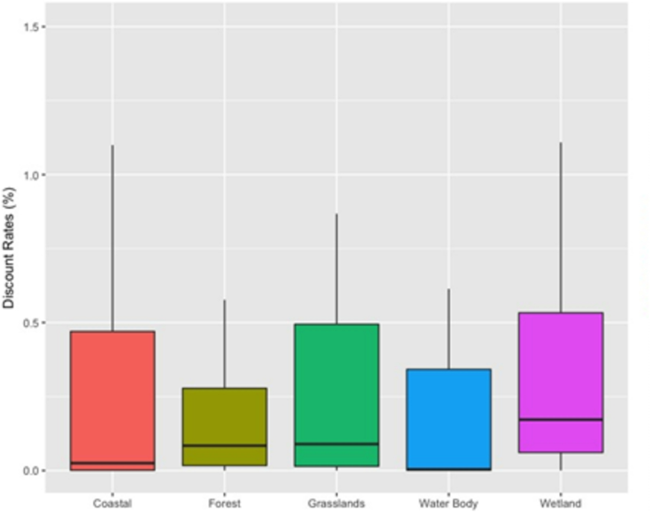


Benefits$_{Development}$
B_2
Small gain to development
B_1
C_2
B
A
C
Large gain to development
Large loss of benefits from nature
Small loss of benefits from nature
C_1
Benefits$_{Protection}$



Number of Entries
100
90
80
70
60
50
40
30
20
10
0
UK
Netherlands
Greece
Finland
Spain
Italy
Belgium
Poland
Sweden
Germany
Turkey


Habitat
Coastal
Forest
Grassland
Wetland/Water Body



1.5
1.0
0.5
0.0
Discount Rates (%)
Coastal
Forest
Grasslands
Water Body
Wetland