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Environmental management problems, future generations and social decisions[1]

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ABSTRACT

The decisions of many individuals and social groups, taking according to well-defined objectives, are causing serious social and environmental problems, in spite of following the dictates of economic rationality. There are many examples of serious problems for which there are not yet appropriate solutions, such as management of scarce natural resources including aquifer water or the distribution of space among incompatible uses. In order to solve these problems, the paper first characterizes the resources and goods involved from an economic perspective. Then, for each case, the paper notes that there is a serious divergence between individual and collective interests and, where possible, it designs the procedure for solving the conflict of interests. With this procedure, the real opportunities for the application of economic theory are shown, and especially the theory on collective goods and externalities. The limitations of conventional economic analysis are shown and the opportunity to correct the shortfalls is examined. Many environmental problems, such as climate change, have an impact on different generations that do not participate in present decisions. The paper shows that for these cases, the solutions suggested by economic theory are not valid. Furthermore, conventional methods of economic valuation (which usually help decision-makers) are unable to account for the existence of different generations and tend to obviate long-term impacts. The paper analyzes how economic valuation methods could account for the costs and benefits enjoyed by present and future generations. The paper studies an appropriate consideration of preferences for future consumption and the incorporation of sustainability as a requirement in social decisions, which implies not only more efficiency but also a fairer distribution between generations than the one implied by conventional economic analysis.

1. INTRODUCTION

In order to consider the problems arising in the management of natural resources and the environment it is first necessary, to describe the various types of goods involved in economic terms. The classification presented in section 2 starts from the classical divergence between private and collective goods and it is expanded with new concepts that give rise to new types of goods such as, for example, the ones that we call *subprivate* goods, *hypercollective* goods, and *intergenerational* goods. The conceptual framework is therefore enhanced and the conditions for a rigorous analysis are improved. It is also necessary to refine the conceptual basis provided by economic theory on *externalities* in

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order to analyze not only the classical divergences between individual and collective interest, but also the opportunities for action in a non-ideal context. These questions are considered in section 3 and the conflict that exists between present and future generations is analyzed in detail, from the perspectives of both equity and efficiency.

Conventional methods of economic evaluation of projects and policies are usually used to help decision-makers. The application of these methods to intergenerational problems, such as climate change, has been widely criticized because it does not take the interests of future generations into consideration adequately. Section 4 analyzes the limitations of conventional analysis of intergenerational problems and proposes an alternative solution which incorporates the existence of different generations and the requirement of sustainability in long-term projects. Section 5 studies an intergenerational weighting showing social preferences, and proposes an evaluation methodology which aggregates the costs and benefits of projects through this weighting. Section 6 analyzes the individual and social optimality of intergenerational investments from an individual and social point of view using an overlapping generations model with intergenerational altruism. Finally, section 7 summarizes the main conclusions.

2. COLLECTIVE GOODS AND OTHER PECULIARITIES

2.1 Definitions and classifications

The notion of *collective good* emerged as a response to a legal action against Thomas Jefferson for using the idea of a mechanism that was patented. The first example of collective good was therefore an idea. Jefferson argued that one should not pay for the use of an idea because *"its peculiar characteristic is that nobody possesses less of it due to the fact that another posses it completely"*, i.e. because there is no any opportunity cost for anybody. The economic definition of *collective good* comes from Samuelson (1954). It is opposite to that of *private good* because of its consumption characteristics and it has no relationship with the type of ownership of the good. For a good to be *collective*, it does not matter whether the ownership is public, private or mixed.

In a *private good*, such as apples or tissues, there is rivalry in its consumption because if a unit is consumed, the total availability for consumption diminishes in this unit. However, in the case of a good with collective good characteristics, such as the protection provided by the ozone layer, all consumers consume the same amount — all the available quantity. It is obvious that the environment and natural resources clearly have collective good characteristics.

In a *pure collective good*, consumption is unavoidable, the cost of access is zero, and there is no possibility of excluding any consumer. This creates serious problems for financing the provision of this type of goods. In fact, given that nobody can be excluded from its consumption, even if they have not contributed at all to financing the provision of the good, there are no incentives for contributing to financing the provision of the good, which is known as *free rider* behavior. The same problem arises when the aim is to discover a consumer's valuation of the good. The individual will tend to undervalue (overvalue) the good if he/she thinks that his/her fiscal contribution will be greater (smaller) as greater (smaller) is the valuation stated. A prior requirement for efficient provision is knowledge of the good's economic value, the demand curve. As a consequence, in order to achieve an optimal provision, a demand revelation mechanism should be used, i.e., a procedure that induces consumers to tell the truth in their own interest.

Local collective goods

Goods that have collective good characteristics for only a subset of consumers and not for all of them are called *local collective goods*. These goods behave as pure collective goods *within* their range and as pure private goods *between* different ranges, such as the services that provide the clock of a church tower.

Hypercollective goods

If one good is a collective good, the incorporation of an additional consumer does not affect consumption by other consumers. This study proposes calling goods whose available consumption increases when the number of consumers increases *hypercollective goods*. The utility obtained from the consumption of discotheques depends on the quantity of consumers. The same happens in certain types of associations, unions, political parties and groups of persons with similar preferences on specific issues, which provide the *relational goods* defined in Uhlaner (1989) –because the utility of each member increases with the total number of them.

Congestion. All goods with collective good characteristics can be affected by *congestion*. This means that when the quantity of consumers increases above a certain critical threshold, it is necessary to increase production in order to keep the characteristics of the good unchanged. For example, when a bus is full, it is necessary to use another bus to satisfy an additional user of this local collective good. Furthermore, in order to maintain the quality of a hypercollective good such as the Internet, it is necessary to enlarge its capacity when a congestion threshold is achieved.

Subprivate goods

In a private good, a unit consumed reduces the total quantity available for posterior consumption by exactly this unit. We propose calling those goods whose available consumption decreases by more than one unit when a unit is consumed *subprivate goods*. The typical example is the use of the urban underground system by networks of collective services – see Pasqual and Riera (2004) - given that the space actually occupied is much lower than the total space disabled for other uses. Furthermore, depending on the fishing technique employed, for each ton of fish captured useful for human consumption there is a loss of much more tons of marine life. In order to consume one actual unit, it is necessary to produce K units ($K > 1$) of the subprivate good. Consumption efficiency (K) can be measured by observing how the total quantity available for consumption falls as a consequence of the actual consumption of a unit of good:

$$K = -\Delta \text{ available quantity } / \Delta \text{ consumed units}$$

The goods can be characterized, according to the degree of their private/collective characteristic, using the K factor of efficiency in consumption:

$$\boxed{\text{Reduction in available quantity} = K \cdot (\text{quantity consumed})}$$

The values of K for each type of the characterized goods are:

Type of good	*K value*
subprivate	K > 1
pure private	K = 1
local collective	0 < K < 1
pure collective	K = 0
local hypercollective	K < 0
hypercollective	K < 0

Durable goods

A good is durable if it is not exhausted in only one act of consumption, when continuous use during a certain time period is possible and the various consumption acts take place before there is an appreciable deterioration of its basic characteristics. The characteristic of durable good is compatible with that of private goods – such as ties and lighters - and with that of collective goods – such as the force of gravity, the English language and the theorem of the inverse function. Unlike durable goods, non-durable goods are those goods whose consumption leads to the immediate destruction of the good, such as peanuts. A distinction should be made between those that are recyclable and those that not. A can of beer can be recycled, i.e., the material can be reclaimed at a certain cost. However, the use of oil as fuel completely destroys it for economic purposes, with no possibility of recycling it.

Intergenerational goods

An especially interesting case of a durable good is all those goods with a duration of two or more generations, and those of unlimited duration in particular. For these types of goods, we suggest the name of *intergenerational goods*. The set of goods that constitute a culture and renewable goods are typical cases, not only of collective goods, but also of intergenerational goods, given that their benefits can be extended to an unlimited quantity of generations.

Intergenerational collective goods

Extending the definition of collective good to the intergenerational level, we obtain *intergenerational collective goods*, which are characterized by the feature that consumption by one generation does not at all limit consumption by the following generations. As a consequence, these goods are by definition sustainable. The characteristics of *intergenerational collective goods* are compatible with those of collective goods, local collective goods, private goods and any others within one generation. For instance, a jewel is a pure private good, a microclimate is a local collective good, the ozone layer is a pure collective good and Internet is a hypercollective good, but all of them are *intergenerational collective goods.*

Renewable goods

A good is renewable, in the strict sense, when it is possible to have at one’s disposal a certain minimum quantity of the resource for an unlimited time, with no need for human intervention because there is an automatic regulation of incomes and outcomes. The water of an aquifer, fishing resources, forests, and the stork population are examples of renewable goods. Logically, the characteristic of renewability does not entail the characteristic of indestructibility - it is easy to overexploit a forest or an aquifer for a short space of time or to annihilate the storks, destroying these flows of wealth forever. If biological goods are consumed at under their reproduction rate, the total available good for the future does not diminish because the mass recovers quick and automatically. However, the overexploitation of this type of resources entails the reduction of the quantity available for the future, and in extreme cases, the destruction of the resource. The non-biological ones, also named *environmental goods*, such as air, ozone layer, or oceans, do not reproduce and have a limited capacity for autoregeneration. If use does not surpass the limit of autoregeneration they could be used indefinitely as if they were *free goods* (goods whose opportunity cost is zero), while the result of overexploiting them is the continuous loss of quality.

Transformable goods

Here we propose calling those goods where it is possible to change or modify their subprivate, private, collective, hypercollective, intergenerational, durable or non-durable characteristic *transformable goods*. A natural space is a local collective good but it can be used as if it were a pure private good if access is restricted to one person only. An art collection can be consumed as a collective good if it can be observed by any consumer, as a private good if it can only be enjoyed by its owner, and as a subprivate if it rests forgotten in the basement of a museum. The degree of transformation is reflected in the modification of the K factor of consumption efficiency. In addition, the duration of the goods is also transformable in general. It is as possible to ensure the survival of species that would disappear without human intervention as to irreversibly destroy a renewable good. There are multiple intermediate possibilities because the duration of a good can be modified in one or more periods. The duration of manufactured goods is a control variable for the maximization of private benefits by the producer, the chosen duration is systematically lower than the optimal[2] (planned obsolescence) and entails important external costs due to the increase in the use of materials and the generation of residuals. Increasing the duration of a manufactured product constitutes then a good measure of environmental policy, because the greater the useful life of one good, the lower the use of materials and the quantity of residuals produced. A mild transformation of the characteristics of a collective good, in order to make it less pure, has its advantages. An example is the restriction of the access to a natural park, which may be a necessary measure for the preservation of this space. In other cases, it is useful to remove the characteristic of non-exclusion in order to make private provision of a collective good feasible, and thus avoid the possible financial constraints of the public sector.

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[2] In the absence of regulation, the duration of the products is lower than the optimal level and the quantity provided is inefficient due to excess. This is due to the fact the external cost produced by the residual outputs is not taken into account. The optimal duration and, at the same time, the optimal quantity produced and consumed, can be achieved through a tax a la Pigou. See Ocaña and Pasqual (1994).

2.2. A practical case of optimal provision of collective goods: an insurance of water availability

There are many ways to analyze "water" from an economic perspective. Initially, water can be seen as a raw material good, a renewable natural resource that is contained in multiple deposit sites. Economically, human beings derive welfare from the use of water, either as an input in the production of goods and services, or through its final consumption. Usually, water with economic value has to be stored, transported, treated, or evacuated with some additional treatment. Often, all of the above are required at the same time. One way to increase the amount of economically usable water is to reuse it.

Since water is a useful resource (it provides welfare), it will be more valuable as it becomes scarcer. Prices should therefore reflect the relative scarcity of the resource as an economic good. Again, there is the possibility of increasing the amount of economic water in a given system, by enlarging the storage capacity or accessing new deposits, by extending the transportation infrastructure, by de-salting sea water, or by extending the life cycle of the economic water, for instance. The life cycle can be extended by re-using water, after treatment, for higher economic value activities (e.g. agricultural use) than the water would otherwise have been used for (e.g. returning it to a river ecosystem). "Producing" more water implies an extra cost, but also an extra benefit. A cost-benefit analysis could evaluate whether the extra benefit is worth the extra cost or not. To do so, the value of water – its shadow price - has to be approximated. This chapter deals mostly with the problem of how to estimate this water value and how to implement a cost-benefit analysis of water reuse.

2.2.1. A naïf model

Given people's preferences and resources, the quantity demanded of good x, e.g. water, depends on its price p. The direct demand function is therefore $x = X(p)$. The price is used as a value signal and ought to coincide with the marginal cost. If p were not appropriate, the value signal would be biased and the amount of the good x provided would not be optimal. Instead of using the direct one, the indirect demand function could also be used, $p = P(x)$. The function $P(x)$ expresses the maximum price p the consumer would be willing to pay for an additional unit of water, if this is the good under consideration. In other words, $P(x)$ measures the marginal valuation of water by the consumer.

As an example, consider the demand schedule in table 1. If consumption were of 2 units of water, the (gross) social benefit would be 25 (19 monetary units for the first unit of water, and 6 for the second), while with 3 or more units the (gross) benefit would always be 28 monetary units.

Table 1. Actual marginal value per unit of water consumed

Physical units	1st	2nd	3rd	4th
Marginal valuation	19	6	3	0

Let us now suppose that the cost of providing water is that shown in table 2. With the data shown in both tables, the optimal consumption – the one that maximizes the (net) social benefit - is 3 units. The net benefit, or *surplus*, associated with the 3 units of water is $E^* = (19 + 6 + 3) – (1 + 1 + 2) = 24$ monetary units.

Table 2. Marginal cost per unit of water consumed

Physical units	1st	2nd	3rd	4th	...	Tth
Marginal cost	1	1	2	2	2	2

The result is the same as the one which would arise from a perfectly competitive market, in the absence of externalities, collective goods and increasing economies of scale. But the availability of water for consumption has collective good characteristics, and it is therefore susceptible to the free-rider problem. To illustrate this point, imagine that consumers understate their interest in the good. Instead of revealing the true demand schedule (table 1), they send signals according to table 3. With the cost schedule from table 2, the new “optimal” provision of water would be 2 units, since it is the amount that maximizes the social surplus $E^* = (19 + 6) - (1 + 1) = 23$ monetary units. There would therefore be a loss of welfare associated with the understated signals.

Table 3. Understated marginal value per unit of water consumed

Physical units	1st	2nd	3rd	4th
Biased statement (-)	12	5	1	0

If instead of understating their interest, consumers overstate it, the solution is again not optimal. To illustrate this, consider the new schedule in table 4. Now the “optimal” consumption would be 5 units of water, since this is the amount that produces the maximum surplus $E^* = (19 + 6 + 3) - (1 + 1 + 2 + 2 + 2) = 20$ monetary units. In conclusion, to achieve an optimal assignation of water, the free-rider problem has to be avoided.

Table 4. Overstated marginal value per unit of water consumed

Physical units	1st	2nd	3rd	4th	5th	6^{th}
Biased statement (+)	20	17	8	4	3	0

There are still more problems to be aware of. The supply side might not be competitive. Let us consider for example a market with a single firm providing water to the locality, and say the firm is public and interested in enlarging its budget. Assume that the only restriction of the firm is to be profitable. In this framework, the provision will be the largest possible, while the surplus is strictly positive. Taking the true demand revelation of table 1as an example, the amount of water provided would be 14 units, and the surplus would be lower than optimal: $E^* = (19 + 6 + 3) - (1 + 1 + (12 * 2)) = 2$ monetary units.

In short, for the water projects to be efficient, the strategic behavior of both consumers and providers (among other problems) has to be avoided. To ensure this, all agents should have incentives to reveal their true preferences and behave efficiently. This is the subject of the next section.

2.2.2. The proposed model

Let water be demanded for both production and final consumption purposes. Suppose that the total amount of disposable water is usually sufficient. However, with a given probability, there may not be enough water to always satisfy both types. In deficit situations producers and consumers that demand water bear a cost associated with the shortage. In order to reduce the cost, an investment plan to increase water availability through a desalination plan is proposed. The unitary investment costs are known, but in order to determine the scale of the project, its (gross) benefits are to be estimated.

Consider that access to desalinated water has the characteristics of a collective good, and therefore does not offer individual incentives to contribute to its financing. All the demand agents are interested in the project being undertaken, but the free-rider problem arises. If individual agents are asked for their willingness to pay for the project, they will tend to understate (overstate) their value if they believe the answer would influence the amount of taxes they will have to pay. But the estimated demand function is drawn from the individual answers of the agents, and from it the (gross) social benefit is computed and the optimal amount of water determined. A procedure that ensures that it is in the best interest of each individual agent to honestly reveal his/her maximum willingness to pay would overcome the problem. There are several such procedures. The one proposed here is a variant of the Thompson (1966) mechanism.

The Demand Side

When the provision of one collective good has to be chosen from two or more alternatives, each agent may prefer one over the others, and their choices do not necessarily coincide. When the socially chosen alternative is not the one that a given agent prefers, he/she therefore bears an opportunity cost. However, as shown below, an insurance mechanism gives incentives to individuals to reveal their “true” opportunity cost. In this way, the demand revelation problem can be overcome, because the good that provides the largest social benefit is also the one that provides the minimum social opportunity cost.

To exemplify the problem, suppose one wants to find out the individual’s maximum willingness to pay for a collective good, such as desalinated water in case of drought, for each potential consumer (or a sample of them) - in other words, to find out the individual and social losses of a drought season. Let us say that the government makes an announcement saying that it is prepared to offer insurance against drought (or water scarcity in general) to those who want to purchase it. The government informs that the probability of not having scarcity (event P) is p, while the drought (event Q) has a probability (1-p) of happening. For the mechanism to work properly, agents have to believe that the announced probability is the actual one. The unitary price to be paid for contracting insurance coincides with the drought probability (1-p), and at that price agents can insure for the amount of money they want. As shown below, this mechanism gives agents incentives to subscribe to the insurance for a quantity equal to the expected loss.

Assume the actual value (a, b, …) of each agent (A, B, …) is that expressed in table 5, where the aggregate willingness to pay is $V'(\cdot) = a + b + ... + n$. If agent A does not subscribe to the insurance (no S), his/her mathematical expected benefit (E_A) is the probability of having water (p) multiplied by his/her benefit (a) from using the water:

$$E_A \text{ (no S)} = pa \tag{1}$$

Table 5. Actual valuation of (desalinated) water during a drought

Agents	Valuations
A	a
B	b
...	...
N	N

If agent A contracts the insurance against drought, he/she has to decide the optimal amount in monetary units to receive in compensation (a + a'), where a' is the bias –or lie - introduced by agent A when revealing his/her valuation. When a' > 0, agent A overstates his/her interest; when a' < 0 he/she understates it; with a' = -a, the amount of the insurance is zero (no S); and finally, with a' = 0 agent A reports his/her actual (unbiased) valuation. The insurance premium will be

$$H_A = (1 - p)\,(a + a') \qquad (2)$$

where (1-p)a' is the overpayment (or underpayment) of premiums due to the lie a' by agent A concerning events P (no drought) and Q (drought). The compensation payment for loss if Q occurs is the insured value (a + a'). The net benefit agent A obtains depends on whether P or Q occurs, which happens at probability p and (1 – p) respectively. The mathematical expected benefit for agent A, ($E_A(S)$), if he/she takes out insurance is therefore

$$E_A(S) = pa + (1 - p)\,(a + a') - H_A \qquad (3)$$

And substituting H_A from (2),

$$E_A(S) = pa \qquad (4)$$

An initial conclusion from (4) is that the expected net benefit to an individual agent from the insurance is regardless of the lie a'. Furthermore, (4) coincides with the expected benefit without insurance, (1). However, there is an important difference. The *risk* in subscribing to the insurance at the honest valuation is different to subscribing to it at a biased valuation, or in not subscribing to it at all.

Without insurance, the agents will obtain either the value a or zero, depending on whether P or Q occurs, which depends on the risk of drought, which might not be negligible. Furthermore, if agent A gets insured against Q, but lies (a' $\neq$ 0), and only P occurs, he/she obtains the actual benefit (a), and pays (1 - p) (a + a'), which reports a net benefit of

$$pa - (1 - p)a' \qquad \text{if P occurs}$$

It can be seen that the payoff decreases as a' increases

On the other hand, if Q occurs, agent A will get back the amount (a + a') and pay (1 – p) (a + a'), which implies a net benefit of

$$p(a + a') \qquad \text{if Q occurs}$$

This monetary amount increases with a’. Table 6 summarizes the benefits from the two events.

Table 6. Payoffs from events P and Q

Event	Value	Gross benefit	Premium cost	Net benefit
P	a	a	(1 - p)(a + a')	pa - (1 - p)a'
Q	0	(a + a')	(1 - p)(a + a')	pa + pa')

With “dishonest” insurance, agent A gets the same net mean expected return –as derived from (4) - than with an honest insurance. However, the difference in the net benefit between P and Q is precisely a’. Agent A fixes the variance he/she wants, since all the benefits but a’ are regardless of the event that occurs. As a result, the larger the bias a’, the larger the risk will be. And for an agent who does not subscribe to the insurance, the risk gets larger with his/her actual value a, thus giving a greater incentive to participate in the insurance market.

If an agent is risk averse, he/she will prefer the less risky option if both offer the same expected return but different risk levels. In this case, the preferred option is a’ = 0. In other words, he/she will prefer to reveal an unbiased valuation.

Obviously, the case of agent A can be extended to the other agents, B, C, etc.… No agent will have an incentive to lie, if he/she is risk averse, which was the desired result for the mechanism proposed. Table 7 sums up the different results.

Table 7. Different insurance combinations

	Net benefit Without insurance	Net benefit with Insurance	
		Dishonest (a' ≠ 0)	Honest (a' = 0)
Event P	a	pa - (1 - p)a'	pa
Event Q	0	pa + pa'	pa
Expected return	pa	Pa	pa
Benefit range	[a] - [0] = a	[pa - (1 - p)a'] - [pa + pa'] = a'	[pa] - [pa] = 0
Does risk exist?	YES	YES	NO
Risk increases	with value of a	with value of a'	NO

A remarkable characteristic of this mechanism is that the incentives to reveal true values are regardless of the probability p. However, the net benefit for consumers increases with p. On the other hand, the government (which issues the insurance) collects more money as p decreases. This would usually pose a problem, since the government would have incentives to collect more. In this case, though, the probability is observable (either there is a drought or there is not), which makes the problem less likely to happen.

The Supply Side

Once the actual demand is known, the question is to determine the optimal investment I* in desalination to increase the probability p of not having water shortages. In other words, the value I* that maximizes the net social benefit has to be determined.

Let p(I) be the function that relates the non-drought probability with the investment level, with $p'_I > 0$, $\forall I \geq 0$. Suppose that an investment of value I is undertaken during the initial time period (0). As a consequence, a value V (associated to event P with probability p) is obtained at each time period during T periods, as reflected in table 8.

Table 8. Investment and returns per each time period

0	1	...	T
- I	pV	...	pV

The Net Present Value (NPV) of the investment is

$$NPV(r) = -I + pV[1/(1+r) + 1/(1+r)^2 + ... + 1/(1+r)^T] =$$

$$= -I + pV[1/r - 1/r(1+r)^T], \qquad (5)$$

which yields

$$NPV(r) = -I + pV/r \qquad (6)$$

when T is large, with r being the discount rate.

The optimization program is

$$\max_{I \geq 0} NPV = -I + pV/r$$

and the marginal optimality condition is

$$p'V = r \qquad (7)$$

The condition means that investment has to reach the level where its marginal return $(\delta p/\delta I)\cdot V$ equals the marginal cost of capital, r. Since it is not certain that the investment generates net benefits, the optimal level I* is desirable when NPV(I*) > 0, and there should be no investment whenever NPV(I*) ≤ 0.

For instance, let V’ = 2000 be the marginal social value of securing a water supply, and let the relationship between the investment level (I) and the non-drought probability (p) be the one shown in table 9.

Table 9. Relationship between investment and probability of non-drought

I	0	500	600	800	1200	1800	2750	4000	7000	9000	15000
p	0.3	0.35	0.4	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80

Applying the optimality rule – adapted to the example case, which is discrete - and taking an opportunity cost of capital of r = 10%, the following expression can be found:

$$(\Delta p/\Delta I)\cdot V = r = 10\ \% \qquad (8)$$

Table 10 shows that the optimal level of investment in the example would be I*=2750 monetary units. This would ensure a water supply with a chance of 60%, with a NPV of

9250. Note that this is larger than NPV(I = 0) = 6000. Therefore the $\Delta NPV = 3250 > \Delta I = 2750$.

Table 10. Optimal level of investment in relation to the other variables

I	0	500	600	800	1200	1800	**2750**	4000	7000	9000	15000
P	0.3	0.35	0.4	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
$(\Delta p/\Delta I)V$	-	20	100	50	25	16.67	10.52	8	3.33	5	1.67
NPV	6000	6500	7400	8200	8800	9200	9250	9000	7000	6000	1000

For this market to work correctly, the insurance agency needs to have incentives to apply the optimality rule in (7). Suppose the insurance agency wants to maximize its benefits. In order to obtain an efficient result it would be sufficient for the agency to pay the quantity V in case of drought (event Q with probability 1-p), and receive an inflow of S (or its equivalent s per period, where s/r = S) that ensures its financial balance. The insurance agency program would then be

$$\underset{I \geq 0}{\text{Max}}\ NPV = S - I - (1 - p)V/r,$$

that is,

$$\underset{I \geq 0}{\text{Max}\ NPV} = S - I - V/r + pV/r \qquad (9)$$

Since both S and V/r are constants, (9) yields the same marginal optimality conditions, $p'V = r$, as the previous programs. It is therefore socially desirable to have the agency maximizing its net benefits.

2.2.3. Some remarks on the provision of insurance of water availability

Before estimating the optimal amount of desalinated water to be provided, it is advisable to characterize the good from an economic perspective. It is especially important to ascertain whether – or to what degree - the good is consumptive. Depending on the good's characteristics, it is not reasonable to expect that the market will provide efficient results by itself. Both consumers and producers may have incentives (additional personal benefits) to behave strategically. As a consequence, it is advisable to design procedures that are compatible with individual incentives, and therefore individual decisions will lead to efficient results.

For this, a mechanism has been proposed for the demand side, based on an insurance subscription. In its original version, the mechanism only operates on the demand side, and it is aimed at choosing between two alternatives. The mechanism proposed here, however, works for the selection of the optimal provision of collective goods.

Furthermore, in the original mechanism the probability of the event is exogenous, unobservable, and plays no role in it. Furthermore, agents have to believe that the exogenous probability given is the actual one. In the adaptation carried out here, the probability is an endogenous variable, is observable, and is therefore less likely to be manipulated.

Since the supply side has also been modeled in a way that meets the incentive compatibility criteria for producers, the model is complete, and the expected results ought to be close to the optimum.

3. THE PROBLEM OF EXTERNALITIES

3.1. Characterizing the problem and refining the concept

An externality is any cost or benefit that is imposed involuntarily and without compensation to any person. An externality arises when the range in which decisions are taken is smaller than the range in which the costs and benefits of an economic activity take place. In this way, not all the relevant costs and benefits are accounted for, but only those that are inside the range of the decision – *the privates* - obviating the rest – *the external*. As an example, if the range of the decision for a thermal power station project is the country, the costs that acid rain causes in the forests of other countries will tend to be obviated, because they are *external costs.*

When the activities of an economic agent, either producer or consumer, affect the opportunities for activities by another economic agent, and the party causing this effect does not pay for it, then this agent is causing an externality. The destructive use of air, water or forests, as well as cultural production and technological innovation, thus affect subsequent opportunities for using these resources, in both production and consumption. In particular, the decisions taken by present generations positively and negatively affect the opportunities for action of future generations.

When the externalities are *shiftables* –Bird (1987)- the first receptor of the externality can stop receiving its effects by transferring it to others. Some typical examples are the transport of residuals away from the area where they are generated and the change in the route of heavy transport. The simplest and most direct way of transferring an externality is transferring the activity that causes it: e.g. the location of highly pollutant industries in developing regions constitutes a widespread application of the opportunities for transferring an externality. The transfer of externalities is automatic in some special cases, as happens with a great deal of the atmospheric pollution generated in a city. If one tries to solve this kind of externalities, it is preferable, *ceteris paribus*, to act the closest possible solution to the producer of the externality to avoid the extra social cost of the successive transfers.

If the quantity of externality is the same for all the persons suffering from it and coincides with the total quantity produced, the externality is said to be inexhaustible – Bator (1958) - i.e., that it has the characteristics of a *Samuelsonian* collective good. The reduction of the ozone layer as a consequence of consumption and production activities causes an externality for each person that does not depend on the quantity of individuals, although all of them suffer the same quantity of this impact. Signs and symbols have this characteristic, and in general, so do all elements related with culture, from a principle of physics to a literary work, and of course, the climate of the planet. The externality would be *locally inexhaustible* if it fulfills the definition, but only within a locality, e.g. modification of the microclimate in an area due to deforestation. An interesting case is the called *network externality* – Katz and Shapiro (1985) - in which the impact of the externality not only falls with the quantity of consumers but it increases, meaning it has *hypercollective good* characteristics.

It is normal to consider the externality as a flow, i.e. the externality occurs during a certain time period and when it stops the original situation returns. This is true of light pollution and air congestion. In this case there is a *flow externality.* However, in other cases the effects of the externality do not disappear when the activity that has produced it ceases. In this case there is a *stock externality* - Doeleman (1988) - because its effect is cumulative, as is the case with DDT in the human organism, the disposal of mercury in the sea and the production of radioactive waste. An activity that can cause a stock externality would not be relevant if the system is capable of absorbing the externality without an appreciable change in the basic characteristics of the affected resources. It would be then equivalent to a flow externality. However, the same activity emits a relevant stock externality if the resource crosses a certain threshold of relative scarcity that prevents assimilation without environmental cost. Again, there is a conflict between present and future generations - when a resource is extremely abundant for present generations it is logical that it is exploited at a rate at which it ends up being scarce for future generations. In extreme cases, a stock externality might cause irreversible situations such as the extinction of species which limit the opportunities of future generations. The current level of knowledge about natural processes does not always certain determination of whether an externality behaves as a flow or as a stock.

As is the case with goods, some externalities are transformable, which increases the possibilities of regulation and complicates the process for internalizing these costs. In some cases, it is possible to reduce the cost of an externality by means of simple transformations, such as the compacting of solid urban residuals. Furthermore, if a solid or liquid pollutant is burnt, it becomes another pollutant, which is maybe even more harmful and is more difficult to control as it is gaseous. This might benefit the producer, but it increases the inefficiency of the system as a whole.

In any case where there are negative (positive) externalities as a consequence of the production or consumption of a good, the market allocation of this good will be inefficient due to excess (shortage) as a result of the market not considering all costs and benefits - internal costs are computed while external costs are ignored. Solving a problem of externalities does therefore not mean eliminating the externality but only taking into account its entire value, that i.e. achieving the *internalization* of the external costs (benefits) in such a way that the consideration of the costs and benefits is complete.

An externality is said to be relevant in allocative terms if the social marginal benefit differs from the private marginal benefit, as the latter does not take into account the corresponding external benefit and/or when the social marginal cost is different from the private, as the latter does not incorporate the external cost. A typical example of an external marginal benefit would be the benefit for the whole society from an increase in the consumption of culture by an individual, and a typical case of external marginal cost is the pollution produced by cars.

It might be the case there was an externality in absolute terms, but that the marginal externality was zero in the optimum. In this case there is said to be an *inframarginal externality* – Buchanan and Craig (1962) - which is not relevant in allocative terms providing that the benefit provided by the externality exceeds the costs of avoiding it. Let us assume that there are two technologies for producing output X, A and B. The net private benefit of the activity produced with technology A is of $100, the total external cost due to pollution is $25 and the external marginal cost is zero in the point of optimal production. As the externality is inframarginal, the quantity decided by producers coincides with the optimal quantity and there are no reasons of efficiency to justify public intervention. However, with technology B, the private marginal cost would increase to $4 although the total external costs would be reduced to $1. The producer does not have incentives for adopting the new technology because his/her profits would be reduced, and as technology A does not generate marginal externalities there is no problem by hypothesis, which is absurd. There is no doubt that it is necessary to take all the externalities into consideration, and not only the marginal ones, in order to mitigate environmental problems.

3.2. The solutions of economic theory to the problem of externalities

All the imaginable theoretical solutions to the problem of externalities are variants of a unique solution: *reassigning the property rights.* From an economic perspective, if there is no regulation of any kind, it is as if all the property rights - including the right to destruction -[3] were assigned to polluters. In fact, in the absence of regulation, any potential polluter can pollute by production or consumption activities with no need to pay for it in any way, with no need to ask for permission or give explanations to anybody, as if he/she possessed the entire property rights to the resource that is being polluted. If the cause of the problem lies in the actual allocation of the property rights to the polluters, it is therefore clear that any solution should take a reallocation of property rights into account. A reduction in the quantity of the property rights controlled by the polluters is required.

The basic ways of redistribution or reallocation of property rights are: a- Enlargement of the range considered. b.- Taxation a la Pigou, c- Administrative regulation, d.- Market negotiation and e- Cultural regulation. As will be seen below, these solutions are relatively effective for solving the problems of present generations but do not allow the externalities affecting future generations to be solved.

a- Enlargement of the range considered. An externality is defined as all the impacts outside the range in which all costs and benefits are considered. Enlarging the range is thus enough to make the externality disappear. For example, a country that is part of the European Union has to accept EU discipline which includes the internalization of some externalities.

b- The taxation solution a la Pigou – the *polluter pays principle* - consists of a tax per unit of production or of consumption equal to the value of the external marginal cost, evaluated at the optimal quantity in the sense of Pareto. As it is a tax per unit, the marginal private cost increases by the exact value of the tax, the value of the marginal external cost, so the externality is internalized. Other taxes, such as the one on sales or value added tax, distort the relative prices of goods and cause inefficiency (*dead weight*). However, the tax that corrects externalities improves the efficiency of the system. For this reason, if the collecting capacity of the *Pigovioan* tax is used for reducing or eliminating a classical tax, then there is a double gain, known as a *double dividend.*

c- With the solution by means of an administrative regulation, the property rights pass to the state, which concedes pollution permits to some agents, in set maximum quantities and under certain conditions. Administrative regulation takes multiple forms and is applied in a global way, either specifically or combined. For example, the transit of cars in a city can be restricted when the total pollution overcomes a preset value[4]. This is an

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[3] They also enjoy the right of negotiation of these property rights, although it would not be used. On the one hand, as any potential polluter he/she has the same right, it would be nonsense that a potential polluter paid for something that could be freely obtained. In addition, the purchase of property rights in order to reduce pollution is problematic, because it would be necessary to buy the property rights of all possible polluters.

[4] Paradoxically, the limit is not determined in relation to the total quantity of pollution produced but to the pollution remaining after the winds have transferred a part to other areas.

ideal solution if the prohibition of an activity (making fires in forests) or making it compulsory (primary education) is a good approximation to the optimum, because the administrative and compliance costs are minimal.

d- The market negotiation solution, the so-called *Coasian* solution, is based on free negotiation between two types of agents, those incurring in an opportunity cost if they cannot increase pollution and those that obtain greater utility as pollution falls.

The state possesses all the property rights, transfers a part to some agents according to some prefixed criteria and organizes a market for those property rights. Negotiation takes place between agents that, given the market price of the property rights, received property rights in excess (supply) and those that wish to have a greater quantity of rights (demand), for polluting more or for preventing others from polluting. The resultant prices and quantities coincide with the *Pigouvian* solution under ideal conditions[5] and, they would be the same if all the property rights were given to polluters and if they were given to the victims. Under less ideal conditions, the result will not be efficient and the bias will depend on the distribution of property rights. With the property rights in the hand of polluters (victims), the inefficiency would always be an excess (shortage) of pollution.

Although in some cases it could be a useful solution for solving the externalities in a certain (developed) country, the consequences of applying a similar process between two countries – or two regions in the same country - can be regrettable if the difference in wealth between suppliers and demanders is a large one. In fact, there are many examples of exports of residuals from rich to poor countries at very low prices and with grave global consequences.

e- Cultural regulation, unlike the other solutions, only allows some kind of externalities to be solved - those that depend on individual agents, typically the consumers in some way. The reallocation of property rights is done in favor of society as a whole and there are social sanctions for those that do not follow the rules that are generally conveyed orally. This solution is appropriate as an alternative to administrative regulation and also as a complement to it. It is also useful for avoiding what Kant called the *tyranny of small decisions*, which consists of a high social cost (benefit) caused by multiple individual decisions, each implying a negligible cost (benefit). The main advantage of this kind of solution is its relatively low cost and its stability over time.

3.3. Limitations of the solutions to externalities

In spite of the quantity and variety of good instruments for internalizing externalities, the problem should not be expected to be easily or quickly solved. The internalization of main externalities has a cost, which judging by the policies followed by most countries – hesitant and slow - is too high to be assumed by the current economic system. It seems that the participation of various generations will be necessary in order to assume the economic costs of taking environmental externalities into account.

An important restriction is the one derived from the current administrative structure available. With the exception of countries with a powerful and efficient administrative organization, which is able to detect any negative deviation and solve it immediately, none of the classical solutions could be applied in the form and intensity needed - even the C*oasian* market solution.

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[5] That is to say, under conditions perfect competition, without marginal transaction costs and with a negligible income effect.

The limitations that are inherent in each kind of solution manifest themselves in real applications. Any way of internalization - the *Pigouvian* way or any other - necessarily affects costs and so affects market prices. This is at odds with the need to be competitive in international markets, because countries that do not internalize externalities can offer the same product at a lower price (*green dumping*). Any solution to the problem is therefore more easily applicable in local than in international markets.

In the regulation of externalities, some of the agents causing them are usually unaffected by the correcting tools. For example, if an urban toll is established to reduce city congestion and pollution, it is highly probable that those using ambulances, police vehicles and fire engines, among others, will not be not subject to this tax. Logically, the toll tries to reduce journeys in private vehicles but, undoubtedly, it does not try to stop the activity of the various public services. However, this fact complicates the computation, because now the activity of the users that are exempt from the tax should be subtracted from the optimal quantity in order to determine the remaining quantity for the non-exempt users. Under these conditions, the first best solution would not be achieved, but instead the second best solution in the best of cases.

In any case, the most serious limitations appear when trying to solve intergenerational externalities. Intergenerational externalities exist because the actions of present generations affect the possibilities of future generations. There is also a kind of externality consisting of the fact that present generations have defined preferences concerning the consumption or welfare of their descendants, future generations. There are therefore externalities between present generations and future generations that should be internalized, either if the objective is a redistributive improvement or if it is merely an increase in economic efficiency.

It should be remembered that any imaginable solution to an externalities problem requires an expropriation of propriety rights because in the absence of regulation, these belong completely to the agents that cause them, i.e. the present generations in this case. In the case of the externalities affecting future generations, if these external effects have to be internalized, at least a part of the property rights should therefore be transferred from present generations to future generations. For the moment, there is no practical way of carrying out this transfer and all the property rights belong *de facto* to present generations. The means of management of these natural and environmental resources is therefore *free access* for the present generations, which is the most inefficient of the possibilities.

The limitations of classical solutions are very serious in the intergenerational context. In the *Pigouvian* solution, for example, it is necessary to determine the value of the external marginal cost. In the case of a non-durable externality, such as noise, it is "enough" to find out the valuation of present generations. However, when the externality has durable effects, as is the case when nuclear waste is generated, a language is lost, a species disappears, or pollutants are continuously dumped in the sea, the computation of this cost is different if one considers the perspective of future generations than if the interests of future generations are also taken into account.

The application of a solution *a la Coase* has serious problems. As future generations cannot act in any way in the property rights market, because they do not exist yet, and because they do not have a representative that can negotiate in their name on equal terms with other agents, this solution is not applicable.

It is unreasonable to expect an administrative regulation by means of norms for internalizing externalities to appropriately take into account the interests of future generations, given that future generations do not have anyone representing them before those design and apply the norms.

The same will occur with a *Pigouvian* solution with an externality only affecting future generations. The government does not have incentives to burden its potential voters with a tax benefiting of their descendants, because future generations do not have either a voice or a role in the political arena.

Furthermore, if a member of present generations sees that his/her interests have been harmed, he/she has recourse to the administrative and law system to defend his/her interests. However, this is not possible for future generations, so the possible harm that they suffer would go unpunished, in as far as that they do not have a legally recognized representative that could claim damages in their name.

In conclusion, as any solution needs from the reallocation of property rights, and as future generations do not have any system which allows them to defend their property rights, it can be stated that, for the moment, economic theory does not provide any mechanism for internalizing the externalities that would affect future generations.

3.4. An application of a case of externalities

3.4.1. The choice of the best use for a space

There is a limited space available that can be used in only way from use among different incompatible alternatives. The gross social value of the space in its current state is V^0, and the value corresponding to the different alternatives is V^1, ..., V^n, respectively. Adapting the space to use j involves a transformation cost $C_j \geq 0$, j = 1, , ..., n. Initially, two cases can happen:

Case 1.

$V^0 > V^j$, $\forall$j. In this case, there is a sufficient condition for the transformation of the use of the space, which we call project T, not to be interesting under any circumstances and so the problem is already solved. The best option is the current one, the 0, and the value of the space is V^0.

Case 2.

$\exists$h such that $V^0 < V^h$, h = 1, ..., H. If there is at least one use providing a greater social value than the current use, then there is a necessary condition for project T to be desirable, but this condition is not a sufficient condition. Two things might happen, either $V^0 > V^h - C_h$, $\forall$ h or $\exists$k $V^0 < V^k - C_k$, which is examined next.

a) $V^0 > V^h - C_h$, $\forall$ h. Under these circumstances, the project T is not desirable because the condition is necessary and sufficient for the non-desirability of modifying the current use. In spite of the fact that the use 0 is not the best, because there are better alternatives, the cost of transformation is high enough to prevent the transformation. The value of the space is still V^0, both *ex ante* and *ex post*. If, for any reason, the space was transformed by giving it another use, e.g. use s, then the value of the space *ex ante* would be equal to the maximum value among V^s and ($V^0 - C_s$) and the value *ex post* would be of V^s.

b) $\exists$k $V^0 < V^k - C_k$, k = 1, ..., m, m+1, ..., K. The current use 0 is not optimal because there are K better alternatives and, besides, the change of use implies an increase in value which more than compensates for the cost of transformation C_k. Here there is a necessary and sufficient condition for the desirability of the transformation of T.

It could be the case that V^0 was taken as the valuation *ex ante* of this space, but this, as we will see, would not be correct at all. Before starting the valuation task, the soundness of the K alternatives should be examined. The best alternative in relation to the *status quo* is the use m that fulfills $V^m - C_m \geq \max\{V^k - C_k\}$, and this is the best use of the space[6]. As a hypothesis, we have $V^0 < V^m - C_m$, the maximum that one would be willing to pay for the space in the state 0 is $V^m - C_m$, and the value *ex ante* of the space is for this reason, $(V^m - C_m)$. Carrying out the project T, the *ex post* value changes to V^m, because the cost C_m is a *sunk cost* as it cannot be modified in any way and thus, it should not be taken into account.

To summarize the above,

Cases	0 is optimal	Best use		T, desirable	Type of condition	Space value	
						ex ante	*ex post*
$V^0 > V^j$	Yes	0	$\Rightarrow$	No	sufficient	V^0	V^0
$V^0 < V^h$	no	h	$\Leftarrow$	Yes	necessary		
$V^0 > V^h - C_h$	no	0	$\Leftrightarrow$	No	necessary and sufficient	V^0	V^0
$V^0 < V^m - C_m$	no	m	$\Leftrightarrow$	Yes	necessary and sufficient	$V^m - C_m$	V^m

3.4.2. The distribution of a space among two incompatible uses

Let us assume that there is a total quantity of space $\underline{e}$, which cannot be increased in any way. There are two alternative uses of this space — α and β, which are incompatible. The problem is that of separating those uses and distributing the total space between both uses in an optimal way.

Let us assume there are a users of type α and b users of type β, and that all the users of the same type are identical. The users j have defined preferences over the goods $X_{j,\, j\, =\, \alpha,\, \beta}$, and Y. Y is a pure private good that is available in a predetermined quantity w. The goods X_j are local collective goods, which are produced[7] using the private good as an input (Z_j) according to the functions

$$X_j - f^j(Z_j) = 0 \quad \phi_j \tag{10}$$

being ϕ_j the multipliers associated to shadow prices constraints. As X_j are local collective goods, all the users j will consume the total quantity produced X_j.

The total quantity of private good $\underline{w}$ is distributed between its use as an input and its use as a consumption good,

$$\underline{w} - Z_\alpha - Z_\beta - aY_\alpha - bY_\beta \geq 0 \quad \lambda \tag{11}$$

with λ being the shadow price of the private good.

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[6] Under ideal conditions, as a perfect capital market. In other cases -for example, if there were financial restrictions-, there is the possibility that another alternative would be preferable.

[7] Instead of interpreting $X_j = f(Z_j)$ as the result of a production process it can be seen as the access cost to good j that provides the space e_j.

Consumption of the good X_j requires the space e_j. The total quantity of available space is prefixed in $\underline{e}$, so it is not possible to modify it

$$\underline{e} - e_\alpha - e_\beta \geq 0 \quad \sigma \tag{12}$$

with σ being the shadow price of the space as a resource.

The benefit obtained depends on the quantity of goods X and Y consumed, which constitutes a gross social benefit (SB) of

$$SB = a\Pi^\alpha(X_\alpha, Y_\alpha) + b\Pi^\beta(X_\beta, Y_\beta) \tag{13}$$

The two uses of the space generate negative externalities that are locally inexhaustible. The costs (SC) of X_j depend on the quantity Z_j of the private good employed in its production, on the number of users on the activity j, and on the quantity of available space for each use j,

$$SC = C^\alpha(X_\alpha, e_\alpha, a) + C^\beta(X_\beta, e_\beta, b) \tag{14}$$

The objective is to maximize the net social benefit, NSB = SB – SC, taking into account the production function of X_j and the constraints on the quantity of space and private good Y. The control variables of the maximization program are the quantity of space allocated to each use (e_α, e_β,), the quantity of users (a, b) of each type (α, β), the quantities of the collective goods and the distribution of the private good. Both the quantity of total space $\underline{e}$ and the total income $\underline{w}$, are problem data and cannot be modified.

The marginal conditions of optimality are quite simple:

$$\partial\Pi^\alpha/\partial Y_\alpha = \partial\Pi^\beta/\partial Y_\beta \tag{15}$$

$$\partial C^\alpha/\partial e_\alpha = \partial C^\beta/\partial e_\beta \tag{16}$$

$$\partial f^j/\partial Z_j + \partial C^j/\partial X_j = i\partial\Pi^j/\partial X_j,\ j = \alpha, \beta,\ i = a, b \tag{17}$$

and the interpretation is quite direct:

a) To distribute the quantity of the private good in such a way that there is equality in the marginal benefit for all users

b) To distribute the space between the uses j in such a way that the marginal benefit derived from the space is the same for both spaces

c) To produce the collective goods j in such a way that the sum of the marginal benefits of the users of each type is equal to the cost of production – the *Samuelsionian* condition for local collective goods - plus the cost of the marginal externality – the *Pigouvian* condition for internalizing externalities.

3.5. Some remarks on the problems of externalities

The set of economic instruments for internalizing externalities and providing collective goods is more or less satisfactorily effective in solving the environmental problems affecting present generations. However, these same instruments are inappropriate for considering the externalities that present generations inflict on future generations and for preserving intergenerational goods.

If the world ended with present generations, problems such as climate change or the loss of biodiversity would merit much less attention. The reason for this is simple - the costs for present generations are relatively low, while they are expected to be very high for future generations.

It should be remembered that a necessary condition for the internalization of intergenerational externalities is the existence of a system which allows future generations to have a part of the property rights and to manage and negotiate them with no limitations other than those governing the behavior of present generations. At present, there is no institution which allows property rights to be transferred to future generations. Efforts towards environmental management following conventional economic theory therefore only work in favor of the interests of present generations, in as far as they obviate the interests of future generations.

We understand that the main problem we are faced with, is the conflict between the interests of present generations and future generations. It is for this reason that we devote the second part of this work to analyzing the consequences of this conflict, from both a distributive and from an allocative perspective, focusing our analysis on the appraisal of intergenerational policies and projects, which are usually used to help social decisions in environmental problems.

4. FUTURE GENERATIONS IN PROJECT AND POLICY APPRAISAL

Conventional evaluation and management methods, such as the net present value, have been widely criticized because of their discrimination against the interests of future generations. These methods do not consider the existence of different generations and thus ignore their interests. In short, their applicability to problems with strong long-term effects has been questioned. This is the case of problems like climate change, the ozone layer hole, deforestation and the loss of biodiversity. In this section, we analyze the limitations of conventional economic evaluation of intergenerational problems and propose an alternative for application to projects affecting future generations.[8]

4.1. The limitations of conventional evaluation of long term projects: discounting and future generations

Conventional economic analysis gives less importance to flows that take place in the future (a thorough review of the problems of conventional discounting can be found in Broome (1992) and Price (1993, 1996)). The application of conventional time discounting devalues and practically removes the impacts that occur in the distant future from the analysis. A higher discount rate implies greater discrimination against future generations, although any positive discount rate leads the analysis to strongly devalue and almost ignore distant impacts.

The social discount rate (s) usually used to discount future impacts is expressed with the Ramsey formula:

$$s = \rho + \eta g$$

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[8] See Padilla (2002) for a broader analysis of these limitations and a previous version of our proposal.

where ρ is the pure time preference rate, η is the elasticity of marginal utility (absolute value) of consumption and g is the growth rate of per capita consumption, i.e. discounting is applied because of impatience and the belief that there will be more wealth per head in the future.

Conventional cost-benefit analysis applies the time discount of the present society to discounting all costs and benefits that will occur in the future, as if all future impacts happened to present individuals. The consumption of future individuals is discounted using a rate that shows the impatience of present society, while the logical procedure would be to consider the preferences of present society for the well-being of future generations. An intergenerational weighting appropriately showing these preferences should be applied.

The practical application of the argument of decreasing marginal utility of consumption is also controversial. Applying a high discount rate because of assumed future prosperity could lead to compromising this very prosperity by giving low weight to future impacts (the ‘optimist paradox’).

The individuals originating long-term problems and the ones suffering their consequences are certainly not the same individuals, and we are not certain that these future individuals will enjoy greater well-being. Neither the argument of decreasing marginal utility nor the pure time preference therefore justifies the application of a constant time discounting to long-term impacts.

Many economists still use a much cruder basis for discounting, i.e. the opportunity cost of investment funds. In this way, the resources would be placed in the highest yielding projects, thereby obtaining greater future well-being. This argument is hardly justifiable in the intergenerational context, as it is based on the full reinvestment of the revenues obtained from the exploitation of the resources, which has not occurred in the past and is unlikely to occur in the future (Price, 1996).

The weights to apply to future generations should reflect the altruistic preferences of society and not just be an arbitrary extension of the time preferences of the present (this is analyzed in Section 5). However, considering these altruistic preferences does not guarantee that the interests of future generations are appropriately taken into account. If future generations have certain rights that should be respected, these rights should be included in the analysis.

4.2. Intergenerational equity and the sustainability requirement

Conventional economic analysis implicitly assumes that the Earth and all its resources belong exclusively to present individuals. What is more, the present has the power to decide how to use these resources. As a consequence, the endowment that will reach the hands of future generations is just a residue of the decisions of present individuals and not the result of a negotiation or market including the interested parties. Although there are altruistic preferences that should be considered, these do not solve the entire problem. For a satisfactory solution, both parties (present and future) should arrive at an agreement (which is certainly not possible) or make the recognition of certain rights to future generations based on moral grounds explicit, and act accordingly.

Strong moral, contractual, or deontological justifications lead to rejection of the premise ‘everything belongs to the present’ as a legitimate starting point. Conventional analysis takes the market as the only relevant condition, arguing that this procedure is not value laden. However, this option implies both denying any right to the unborn since they cannot participate in present markets, and accepting that the present can do whatever it pleases without any limit, which certainly is strongly value laden. In order to respect the interests of future generations, present actions should be kept within some limits. It would be more appropriate if these were subject to moral restrictions or, if as a result of a contractual vision, assumed sustainable development as an implicit moral agreement between generations (Barret, 1996; Howarth, 1997).

Much of the literature on sustainability tries to establish different criteria compatible with a development that can be sustained over a long course of time, i.e. compatible with a minimum of intergenerational equity. The most popular definition states that sustainable development is the "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (WCED, 1987, p. 8). This definition implies limiting the present use of resources.

From an optimistic point of view, if every time that natural capital diminishes, an increase in the equivalent manmade capital takes place, then the capacity to maintain the quality of life would not be affected. This is known as the 'weak sustainability' criterion. It somewhat further than conventional economic tools such as cost-benefit analysis because it denies the validity of the Hicks-Kaldor test in the intergenerational context and demands actual compensation if future generations suffer from present actions (Neumayer, 1999). However, it is based on the unreal assumption of perfect substitution between different types of capital. Sustainable development requires making the limits to substitution part of the analysis, and not making very uncertain assumptions that might jeopardize future generations. The respect for future generations' interests needs the implementation of the 'strong sustainability' requirement, a criterion that requires the maintenance of the quantity and quality of natural capital over time, and of some critical levels of certain types of natural capital.[9] Costanza (1994, p. 394) justifies it as a "…prudent minimum condition for assuring sustainability". Ignorance and uncertainties about substitution possibilities imply that there is no feasible way of putting the weak sustainability criterion into practice on a global scale in order to assure sustainability. Present generations will ensure fair treatment for future generations if the levels of the different types of capital do not diminish.

The sustainable development requirement implies assuming a much more favorable distribution of rights for future generations than that contained in conventional economic analysis. Page (1983) states that the life opportunities of future generations will be undiminished if they inherit the same resource base as that inherited by present generations. Bromley (1989) analyzes the possibility of undiminished stocks of natural resources and environmental quality for ensuring intergenerational justice. Finally, Howarth (1997) asserts that the provision of specific endowments of reproduced capital, technological capacity, natural resources and environmental quality may sustain life opportunities for future generations. In conclusion, in order to guarantee fair treatment for future generations, the analysis should consider their right to an undiminished socioeconomic and ecological capacity. The capacity of the present to alter the conditions of life of the future imposes this responsibility.

The recognition of rights to the future, with the application in each case of the necessary proceedings, requires new evaluation and management methods integrating the concerns expressed throughout this work as well as strong institutional support reinforcing it.

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[9] Its quantification might be quite problematic; but it is in any case possible to have some indicators of its evolution.

4.3. Evaluation incorporating the sustainability requirement and intergenerational weighting

This section proposes the application of a new evaluation process incorporating the sustainability requirement and intergenerational weighting. The recognition of rights implied by the sustainability requirement leads to the analysis of intergenerational problems incorporating the obligation of maintaining the economic and ecological capacity that is currently enjoyed. This requires a different evaluation of policies and projects, depending on whether the structure of rights between generations is affected (intergenerational evaluation) or not (ordinary evaluation).[10]

Ordinary evaluation. In the actions that only affect the generations taking the decision, conventional evaluation and management methods are essential for determining the most efficient allocation of resources. Nevertheless, there can be important distributive, ecological, moral, affective, contractual, deontological, cultural, or political reasons for society. These should also be considered in decision-making. As standard cost-benefit analysis follows only the allocative efficiency criterion, in some cases it could be appropriate to include it as merely an element of a more complete decision-making process.

Intergenerational evaluation. When a project has effects on generations not participating in the decision process, various cases should be differentiated. There are projects that will not negatively affect future generations, but there are also some that might harm them. This separation cannot be made with economic information alone - the need to consider geophysical and ecological conditions makes the evaluation and management of sustainability into an interdisciplinary task.

Intergenerational projects not jeopardizing the capacity of the future, in principle, do not give rise to a transaction of rights between generations and therefore do not imply obligations for the present. However, the fact that present generations are (implicitly) assumed to enjoy any future consumption shows that conventional valuation is quite arbitrary. Following the reasoning of subsection 4.1, an intergenerational weighting should be applied that properly shows the preferences of current society regarding the consumption of future generations.

Any action jeopardizing the opportunities to be enjoyed by future generations implies a transaction of rights between generations. In each case, it will be necessary to consider which way of fulfilling the obligations to the future is least costly to the present. The following relevant options could be considered:

a. *Not to carry out the project:* If a project causes irreversible harmful effects to future generations and these cannot be avoided or compensated for, it should be considered as being outside the choice of possibilities. This is the case with exploiting renewable resources indefinitely beyond their regeneration rate, or overexploiting the assimilative capacity of the environment. In addition, when there are serious risks or uncertainties, obligations to the future imply a bigger risk aversion in decision-making. Basic processes and some critical levels necessary for the sustenance of the ecological system should be protected. The information of different scientific disciplines should help to determine which goods require this protection.

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[10] Page (1997) arrives at similar conclusions and differentiates between ordinary and constitutional decisions while Norton (1995) proposes a two-tier interdisciplinary approach.

b. *To undertake precautionary and control measures:* If the modification of the structure of rights that the original project implies is avoidable (e.g. enhancing security systems) and it is still profitable, this option is more appropriate than the first. Conventional computation of costs and benefits (ignoring the future) often leads to ignoring the adoption of security measures or clean technologies, even if they could prevent severe harm to future generations. The obligations of present generations imply that these measures should be included within the unavoidable costs of the project.

c. *Compensation through an associated project:* In some projects it is possible to compensate for the harmful effects on future generations through an associated project (e.g. reforestation).[11] The cost of the compensation should be included in the calculation of profitability, and the way in which this became effective should be articulated. The rights of future generations would thus be protected, with an exchange taking place between generations. In order to permit this transaction of rights a sine qua non requirement should be that decision-makers demonstrate that this compensation will be sufficient and will become effective.

d. *Financial compensation:* This option would clearly modify the composition of the capacity bequeathed to future generations. There should not be any doubts about the possibility of substituting the diminished resources and of establishing an investment fund enabling this future compensation.[12] The damage caused to future generations must therefore be quantifiable in monetary units or, at least, it must be possible to demonstrate that the compensation will, in all likelihood, be satisfactory. Once again, and unlike conventional methods, it should become effective.

The evaluation process, should determine in each case which option is more appropriate and, as argued above, economic information is not enough to decide this. Figure 1, taken from Padilla (2002), outlines the evaluation process proposal.

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[11] This option coincides with the proposal of Markandya and Pearce (1988) on shadow projects.

[12] Costanza and Perrings (1990) idea of environmental bonds could be seen as a way of coming into operation this compensation.

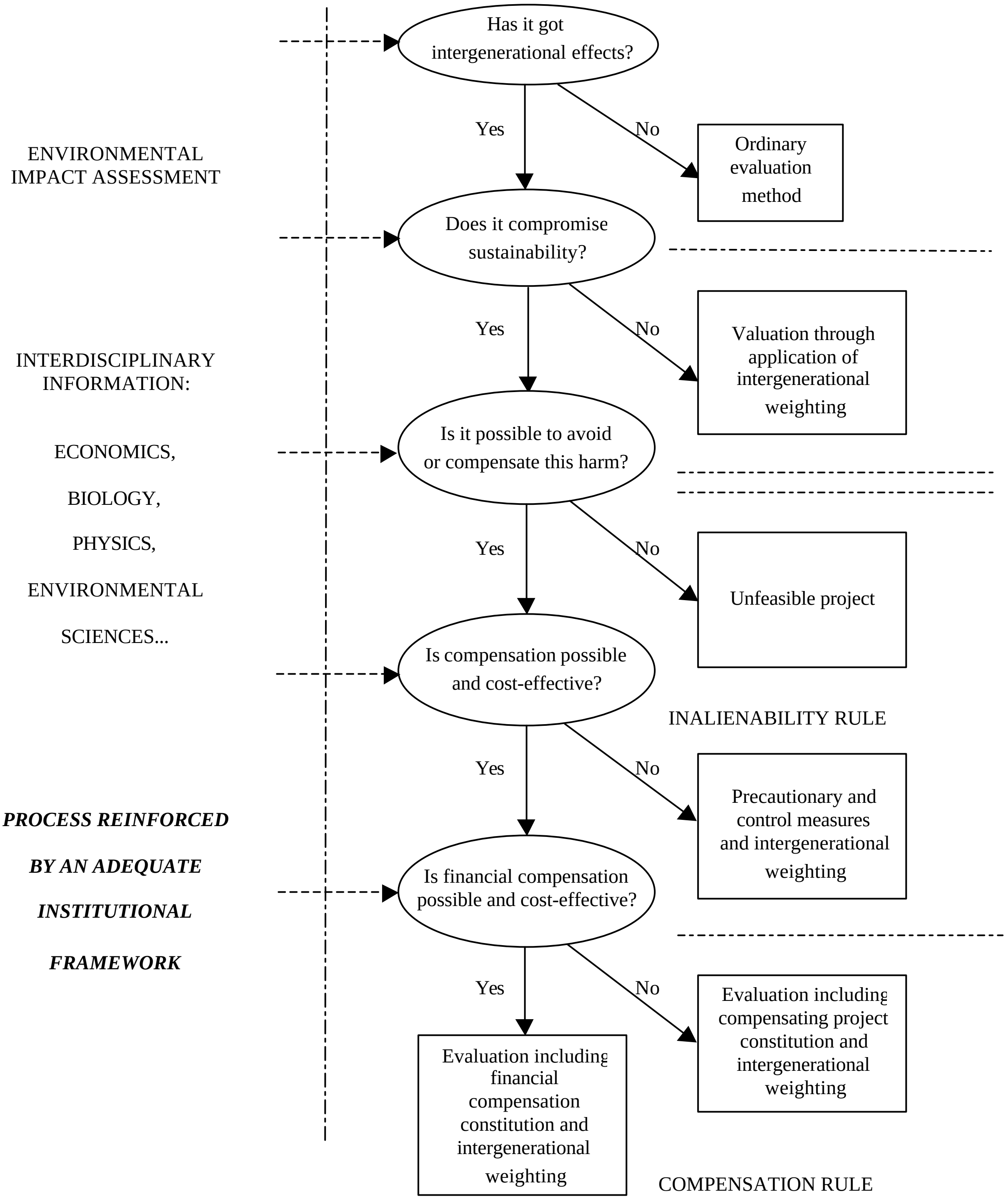

Figure 1. The evaluation process

5. INTERGENERATIONAL WEIGHTING IN LONG-TERM PROJECT AND POLICY APPRAISALS: THE MULTIGENERATIONAL NET PRESENT VALUE

In the previous section we have highlighted that conventional evaluation methods have been broadly criticized because they disregard the impacts occurring to future generations. Their application of time discounting gives a negligible weight to future generations, besides not being very fair, it does not accord with the preferences of society. Applying the time preference of present generations beyond their life-span, as if they were immortal, ignores the fact that these impacts will occur to other individuals. This section tries to overcome this arbitrary premise of conventional economic analysis and studies the consideration of the impacts happening to future generations through an intergenerational weighting which appropriately reflects the preferences of society.

5.1. Intergenerational weighting in a successive generations model with intergenerational altruism

First, the paper considers an economy with successive (non-overlapping) generations. In this model, society is composed of one generation of N individuals, which at the end of each period is substituted by another generation of N individuals (their descendants). The utility of present generation individuals is influenced by the utility level of their descendants (non-paternalistic altruism), so the life utility of an individual is:

$$U^n_t = V^n_t + \beta U^n_{t+1} \tag{18}$$

Where V^n_t is the life utility function derived from own consumption of individual n of generation t; $\beta=(1+R)^{-1}\in(0,1)$ is the altruistic parameter; U^n_{t+1} is the life utility function of the descendant, individual n of the next generation.

The utility function can be expressed as the next weighted sum of the satisfaction that the future descendants derive from consumption (V^n_g):

$$U^n_t = \sum_{g=t}^{\infty} \beta^{g-t} V^n_g \tag{19}$$

So, the intergenerational weighting that an individual of generation t applies to his/her descendant of generation g is β^{g-t}.

One of the principal premises of cost-benefit analysis and welfare economics is that the preferences of the individuals that constitute a society should be taken into account. Following the utilitarian criterion, the social welfare function is expressed here as the sum of the utilities of the individuals that comprise society:

$$W = \sum_{n=1}^{N} U^n_t = \sum_{n=1}^{N} \sum_{g=t}^{\infty} \beta^{g-t} V^n_g \tag{20}$$

Hence, the social intergenerational weight applied in moment t to individuals of generation g is $\beta^{g-t}=(1+R)^{t-g}$, which is equal to the individual weight shown in (19). However, this direct result does not hold if the coexistence in society of more than one generation is considered, as shown in the next subsection.

5.2. Intergenerational weighting in an overlapping generations model with intergenerational altruism

Overlapping generations models, introduced in economic analysis by Samuelson (1958), provide the necessary tools for dealing with the coexistence of different generations in society. In the model considered in this section, society is composed of two generations of N individuals each. Thus, in moment t there are N old individuals of generation t-1, with the next utility function:

$$U^n_{t-1} = \sum_{g=t-1}^{\infty} \beta^{g-(t-1)} V^n_g \tag{21}$$

And there are N young individuals, of generation t, with the next utility function:

$$U^n_t = \sum_{g=t}^{\infty} \beta^{g-t} V^n_g \tag{22}$$

Therefore, the intergenerational weighting that any individual of future generation t applies to his/her descendant of generation g is β^{g-t}, which is higher than $\beta^{g-(t-1)}$ the one applied by the ascendant of generation t-1.

Society is composed of two generations that weight the consumption of future generations differently. The valuation of own consumption of an individual of generation t+1 influences the utility of his/her parent (present generation t) through weight β, and in the utility of his/her grandparent (present generation t-1) through a smaller weight, β^2. In the same way, the remaining future generations influence to a different degree the utility of different present individuals according to their propinquity. The social welfare function in moment t is:

$$W = \sum_{n=1}^{N} U^n_{t-1} + \sum_{n=1}^{N} U^n_t \tag{23}$$

Which can be expressed as follows:

$$W = \sum_{n=1}^{N} V^n_{t-1} + \sum_{n=1}^{N} \sum_{g=t}^{\infty} (\beta^{g-(t-1)} + \beta^{g-t}) V^n_g \tag{24}$$

Thus, the social intergenerational weight (μ_g) to apply in moment t to any individual of generation g > t is:

$$\mu_g = \beta^{g-(t-1)} + \beta^{g-t} = (1+R)^{-(g-(t-1))} + (1+R)^{-(g-t)} \tag{25}$$

Clearly, the social weighting to the consumption of future generations derived from social preferences is not equal to any individual weighting. In addition, it clearly differs from the arbitrary weighting that conventional discounting involves:

$$(1+r)^{-(g-t)} \neq (1+R)^{-(g-(t-1))} + (1+R)^{-(g-t)} \tag{26}$$

Inequality (26) shows that in moment t the weight discounting applies to generation g (left hand side) notably diverges from the weighting derived from social preferences (right-hand side). Moreover, it is not possible to express the social weighting as a simple discount factor.

5.3. The Multigenerational Net Present Value

As shown previously, conventional discounting applies an arbitrary weight to future generations. Some authors (Collard, 1981; Nijkamp and Rouwendal, 1988; Bellinger, 1991; Padilla, 2002; Pasqual and Souto, 2003) have advocated in favor of substituting the weights of the time discount factor for an intergenerational weighting applying an explicit weight to each generation. However, they do not specify much about how these weights should be determined. This paper's view is that intergenerational weighting should show the preferences of society regarding the consumption of future individuals.

There is a broad acceptance that the net present value (NPV) is an appropriate method for calculating the profitability in projects affecting only one generation or one individual. Considering that each generation discounts its consumption flows through its own time discount, NPV_t might be defined as the value that individuals of generation t assign to the increase in own consumption generated by the project. We propose the use of the next weighted sum, the multigenerational net present value (MGNPV), for obtaining the social valuation of the project:

$$MGNPV = NPV_{-1} + \mu_0 NPV_0 + \mu_1 NPV_1 + ... + \mu_T NPV_T \qquad (27)$$

Where T is the last generation affected by the project.

The weight to apply to each generation (μ_g) should correspond to the altruistic preferences of individuals that compose society. In the model of two overlapping generations, $\mu_g = (1+\beta)\beta^g$, (except for μ_{-1}, which is 1), and the derived social valuation is:

$$MGNPV = NPV_{-1} + \sum_{t=0}^{T} (1+\beta)\beta^t NPV_t \qquad (28)$$

This method might avoid the negligible weight conventional NPV applies to future generations in long-term projects. Moreover, it takes into account the existence of different generations and the interrelation between their welfare.

A more general expression for the MGNPV, for a society where people life-span is H periods (so there are H generations) and have a child when they are p years old, can be written as follows:

$$MGNPV = \sum_{g=-H}^{0} \left(\sum_{d=0}^{D} \beta^d NPV_{g+pd}\right) \qquad (29)$$

Where d shows the propinquity of the descendant: for d = 0 it refers to individuals of generation g, for d = 1 to children, for d = 2 to grandchildren, and so on. D is the number of generations that are descendants of generation g and are affected by the project.

It should be noticed that the MGNPV does not apply a unique weight to any consumption in a certain moment of time as does the conventional discount factor, but it takes into account both the time preferences of the different generations and intergenerational altruism preferences to show appropriately the preferences of society about the different consumption flows.

5.4. Some comments on intergenerational weighting and MGNPV

An appropriate consideration of the impacts occurring to future generations requires the application of an intergenerational weighting showing the preferences of society. This weighting depends both on the generational structure and the degree of altruism of the individuals, and clearly differs from the weight that involves the application of conventional discounting. Moreover, individual and social intergenerational weighting differ when the coexistence of more than one generation is taken into account.

A correct consideration of individual preferences about future consumption requires that instead of conventional NPV, the MGNPV should be maximized in project appraisal. This new evaluation method overcomes the arbitrariness of other methods, as it considers both the time allocation of own consumption, and the intergenerational allocation.

6. INDIVIDUAL AND SOCIAL OPTIMALITY OF INTERGENERATIONAL INVESTMENTS

In projects appraisal theory, it is usual to recommend the net present value (NPV) or the internal rate of return for determining the optimal level of investment, choosing between alternative projects, or simply, to indicate whether undertaking a specific project is profitable or not. These methods are based on the application of a constant time discounting to the impacts occurring in the future. Any impact that takes place in the very long run — like many environmental impacts — is given a negligible weight. The use of these methods therefore implies taking investment decisions, obviating what will happen to future generations, which usually leads to their interests being harmed. Furthermore, the application of a constant discounting does not follow any justifiable equity criterion and nor does it correspond to the true preferences of society. Future consumption is weighted according to the time preference of present generations. Conventional analysis thus implicitly assumes that present individuals have an infinite lifespan. However, it is obvious that part of the future flows of consumption will be enjoyed by other generations. As a consequence, it would be more appropriate to introduce the existence of different generations into the analysis and to consider the interrelations between them, thereby taking into account altruistic preferences, as we proposed in the previous section with the application of the MGNPV. The intertemporal allocation of individuals' consumption throughout their life-span should not be confused with the intergenerational allocation, which involves different generations. Both are part of the intertemporal allocation of resources and it would be inappropriate to study just one of its components, obviating the other.

The use of an overlapping generations model helps us to consider the efficiency of the prescriptions of conventional methods used for the evaluation of intergenerational investments, and to search which criterion should follow the public evaluation and management of these investments in order to achieve an adequate consideration of preferences. Nevertheless, as we have seen in section 4, the consideration of the interests of future generations might also require the application of certain equity criteria, such as the sustainability requirement.

6.1. An overlapping generations model with intergenerational altruism

We use an overlapping generations model with intergenerational altruism with the following assumptions: the life-span of individuals is two periods, society is composed of two generations (old and young) of N individuals each; at the end of each period the old generation disappears and a new one appears, making the population consist of 2N individuals.

Following a non-paternalistic altruistic model, similar to the one in Barro (1974), we consider that individuals have the following utility function:

$$U_t = V_t + \delta U_{t+1} \tag{30}$$

where V_t is the life utility derived from the own consumption of an individual of generation t; $\delta = (1+R)^{-1}$ is the intergenerational discount factor, which we assume is between zero and one; U_{t+1} is the life utility function of his/her descendant.

The egoist component of the utility function is:

$$V_t = V(C1_t, C2_{t+1}) = u(C1_t) + (1+s)^{-1}u(C2_{t+1}) \tag{31}$$

where $(1+s)^{-1}$ is the discount factor that the individual applies to his/her second period consumption due to his/her time preference; $C1_t$ is the consumption of the individual in year t, when he/she is young; $C2_{t+1}$ is the consumption of the individual when he/she is old; $u(\cdot)$ is the function of satisfaction derived from consumption, which has the usual attributes of increasing utility of consumption $u'(\cdot) > 0$ and decreasing marginal utility of consumption $u''(\cdot) < 0$.

We can rewrite the utility function of an individual of generation t:

$$U_t = u(C1_t) + (1+s)^{-1}u(C2_{t+1}) + \delta U_{t+1} \qquad (32)$$

In this type of model, there is a chain interrelating the utility functions of present generations with successive future generations. The welfare of any future descendant enters into the utility function of the individual who, in order to maximize his/her utility, has to maximize the next weighted sum of the satisfaction that his/her future descendants derive from consumption:

$$U_t = V_t + \delta U_{t+1} = V_t + \delta(V_{t+1} + \delta U_{t+2}) = V_t + \delta V_{t+1} + \delta^2 (V_{t+2} + \delta U_{t+3}) \qquad (33)$$

So, we can express the utility function as:

$$U_t = \sum_{g=t}^{\infty} \delta^{g-t} V_g \qquad (34)$$

In our analysis, we define social welfare as the sum of individual utilities.[13] As a consequence, the altruistic preferences of all the individuals of present society are taken into account in the social welfare function, because their utility functions include these preferences. If we assume that society at moment t is composed of two generations of N individuals, t-1 (old) and t (young), we have the following expression for the social welfare function:

$$W = \sum_{n=1}^{N} U^n_{t-1} + \sum_{n=1}^{N} U^n_t \qquad (35)$$

Using (34) we obtain:

$$W = \sum_{n=1}^{N} \sum_{g=t-1}^{\infty} \delta^{g-(t-1)} V^n_g + \sum_{n=1}^{N} \sum_{g=t}^{\infty} \delta^{g-t} V^n_g \qquad (36)$$

Where n is a dynastic label, so the n individual of generation t+1 is the heir to the n individual of generation t. In order to present a simpler notation, we omit this label in our following analysis.

6.2. The optimality of intergenerational investments

We study various cases of investments affecting more than one generation. We will compare the optimal decisions from individual and social perspectives, and analyze the differences between them and the prescriptions of conventional methods.

6.2.1. Factors influencing on the choice between own consumption and an investment that yields benefits to a descendant

Starting with the altruistic utility function and the social welfare function considered above, we can make an initial approach to the factors influencing the determination of social and individual optimal decisions in intergenerational investments. We start by studying the case of the investment that an old individual gives to his/her descendant.

Firstly, we analyze the individual optimization problem. Looking at the total derivative of the utility function (32), we can deduce that an old individual in society at moment t will sacrifice his/her own consumption, in order to increase the consumption of his/her descendant, up to the following point:

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[13] We adopt an extended version of utilitarianism where we include altruism in the utility function of individuals and not only egoist preferences as the pure utilitarian version does.

$$(1+s)^{-1}u'(C2_t)\Delta C2_t = \delta[u'(C1_t)\Delta C1_t + (1+s)^{-1}u'(C2_{t+1})\Delta C2_{t+1}] \qquad (37)$$

The left-hand side represents the cost in terms of utility involved in sacrificing consumption ($\Delta C2_t$) for investment. The right-hand side shows the increase in utility given by the increase in consumption of the descendant (flows $\Delta C1_t$ and $\Delta C2_{t+1}$) caused by the investment. We can see that in the investment decision, besides the magnitude of consumption flows, there are also other influential factors. These are the altruistic parameter δ, the marginal utilities of consumption, and the time discount. However, in the individual's optimal decision, the time preference applied to the flows enjoyed by the descendant is the time preference of the descendant and not the time preference of the investor, unlike usual decision rules such as the NPV, where the time discounting of present generations is used to discount all the flows of consumption generated by the investment.

We next analyze social optimization. Note that our social welfare function (36) consists of the sum of the utilities of all the individuals present at moment t in society - generations t-1 and t. In the investment of an individual of generation t-1 for his/her heir, all the effects modifying these utilities should be considered. The utility of the investor is affected by the utility of his/her descendant through the parameter δ, and the heir values his/her own consumption applying his/her own time preference.

The level of investment will be optimal when:

$$(1+s)^{-1}u'(C2_t)\Delta C2_t = (1+\delta)[u'(C1_t)\Delta C1_t + (1+s)^{-1}u'(C2_{t+1})\Delta C2_{t+1}] \qquad (38)$$

As in condition (37), the marginal utilities of consumption and the altruistic parameter δ are quite relevant. However, the relative weights of the different consumption flows are clearly different from those of the individual condition because the consumption of the young individual has more weight in the social consideration. This consumption enters the social consideration not only due to the positive effect on his/her ascendant, through the altruistic parameter δ, but also due to its own valuation because his/her utility is part of the social welfare function. Furthermore, in both cases, the time preference is applied taking who enjoys the consumption into account.

In this analysis, we have seen some factors influencing social and individual optimal decisions in intergenerational investments that are not taken into account in conventional methods. These are the altruistic parameter δ, and distinguishing the beneficiary of the various flows of consumption when applying the time discount.

We next incorporate the individuals' budget constraints. We assume that the individuals have an inelastic labor supply in their first period of life, obtaining w_t in exchange, and transfer savings (s_t) to their second period of life at an interest rate r. We should stress that for the case of intangibles and non-market goods, it might not be possible to transfer consumption between periods at the market rate of interest. Moreover, even in the case of private goods, the imperfections of capital markets might prevent this from taking place in an efficient way. These problems suggest that in some cases we possibly cannot go farther than conditions (37) and (38). However, we will obviate these problems in this section, following the same steps as the usual theoretical analysis.

6.2.2. Investment of an old individual that yields benefits to his/her heir, both present in current society

We first analyze an investment by which an individual of generation t-1 can transfer consumption flows to his/her descendant in the period of investment and in the one after it.

The budget constraints of the investor of generation t-1 are:

$$C1_{t-1} = w_{t-1} - s_{t-1} + Y1_{t-1}(b_{t-1}) \qquad \text{(first period constraint)} \tag{39}$$
$$C2_t = (1+r)s_{t-1} - b_t + Y2_t(b_{t-1}) \qquad \text{(second period constraint)} \tag{40}$$

where b_t are the resources that the investor of generation t-1 invests in the project benefiting his/her descendant; $Y1_{t-1}(b_{t-1})$ and $Y2_t(b_{t-1})$ are the consumption flows that receives from the investment b_{t-1} transferred by his/her parent. The investment b_t will yield the flows $Y1_t(b_t)$ and $Y2_{t+1}(b_t)$ to be enjoyed by his/her descendant.

The maximization program of the individual of generation t-1 is:

$$\underset{s_{t-1},\, b_t}{\text{Max}} \quad V_{t-1} + \delta V_t \qquad \text{s.t. (39) and (40)}$$

In the maximization program, we only need to consider the periods in which the decision has a direct impact — the investor's valuation of his/her own consumption (V_{t-1}) and of the consumption of his/her descendant (δV_t), as we assume that the descendant allocates his/her resources optimally.

The first order conditions are:

First order condition with respect to s_{t-1}:

$$u'(C1_{t-1}) = (1+s)^{-1}(1+r)u'(C2_t) \tag{41}$$

First order condition with respect to b_t:

$$(1+s)^{-1}u'(C2_t) = \delta[u'(C1_t)\, Y1_t + (1+s)^{-1}u'(C2_{t+1})Y2_{t+1}] \tag{42}$$

where $Y1_t = Y1_t\,'(b_{t-1})$ and $Y2_t = Y2_t\,'(b_{t-1})$ (we will henceforth use this notation)

Condition (41) shows the optimal level of saving. This is achieved when the marginal rate of substitution between consumption in period t-1 and consumption in period t is equal to the marginal rate of transformation.

Condition (42) tells us the optimal level of investment in the project that the descendant will enjoy. The left-hand side shows the cost in terms of utility of an additional sacrifice of consumption in the second period of the investor's life. The right hand side shows the increase in utility which yielded by the increase in consumption of his/her descendant (flows $Y1_t$ and $Y2_t$) caused by the marginal increase of the investment. The optimal level of investment depends not only on the consumption flows but also on the time preference, the parameter δ showing altruistic preferences, and the marginal utilities of consumption.

Given the assumptions about altruism ($\delta > 0$) and decreasing marginal utility of consumption ($u''(\cdot) < 0$), the investment in a descendant depends on his/her consumption level. This means that if there were the belief that the level of consumption increases with each successive generation, the individual would give a lower weight to the consumption of his/her descendants.

By combining (41) and (42) we obtain:

$$(1+r)^{-1}u'(C1_{t-1}) = \delta[u'(C1_t)Y1_t + (1+r)^{-1}u'(C^1_t)Y2_{t+1}] \tag{43}$$
$$(1+r)^{-1}u'(C1_{t-1}) = \delta u'(C1_t)\,[Y1_t + (1+r)^{-1}Y2_{t+1}] \tag{44}$$

which tells us that it is efficient to invest while the cost (left hand side) to the investor of a marginal increase in the investment is lower than the benefits (right hand side) that it yields. The consumption flows that the descendant receives are considered, and discounted them using the interest rate, but with the reference point of the beneficiary. They are then weighted using the altruistic parameter δ, which discounts the fact that consumption is enjoyed by the descendant and not the investor.

In order to facilitate comparison with the usual methods, and in the absence of better information, if we assume that $u'(C2_{t+1}) = u'(C2_t)$, which is equivalent to assuming that the different generations have a similar consumption level, the condition remains as follows:

$$(1+r)^{-1} = \delta[Y1_t + (1+r)^{-1}Y2_{t+1}] \qquad (45)$$

This condition implies a weighting that notably differs from the one applied in usual evaluation methods, such as the NPV, in which the flows of consumption are weighted taking only the time from the moment of evaluation into account, without considering who enjoys the consumption. However, in expression (45), the consumption of the descendant is considered by applying the time discount from his/her point of view and weighting it by parameter δ, which shows how the investor values the increase in the utility of his/her heir.

In the case analyzed, taking t as the reference point for discounting, the NPV shows us that it is profitable to invest up to the next point[14]:

$$1 = Y1_t + (1+r)^{-1}Y2_{t+1} \qquad (46)$$

As we can see, the NPV does not consider who enjoys the consumption at all. It simply applies the time discounting from the point of view of present generations, as if these consumption flows were enjoyed by them.

Considering that our welfare function (37) is the sum of the utility functions of the individuals of society, the social maximization program for the considered investment is:

$$\underset{b_t}{\text{Max}} \quad V_{t-1} + (1+\delta)V_t \qquad \text{s.t. (39) and (40)}$$

The consumption of the descendant of generation t appears both for the consideration of his/her ascendant δV^t, and for his/her own consideration, because his/her utility is also part of the social welfare function.

First order condition with respect to b_t:

$$(1+s)^{-1}u'(C2_t) = (1+\delta)[u'(C1_t)\, Y1_t + (1+s)^{-1}u'(C2_{t+1})Y2_{t+1}] \qquad (47)$$

The condition regarding the optimal level of saving (41) remains unchanged. The social condition of the optimal level of investment (47) differs notably from the individual one (42). While in the individual case the weight given to the valuation of the consumption of the heir is δ, in the social case this weight is $1+\delta$. This occurs because both the positive effect that it causes on the investor (δ) and the consideration of the young individual as part of the social welfare function are taken into account.

By combining (41) and (47) we obtain:

$$(1+r)^{-1}u'(C1_{t-1}) = (1+\delta)[u'(C1_t)Y1_t + (1+r)^{-1}u'(C1_t)Y2_{t+1}] \qquad (48)$$

$$(1+r)^{-1}u'(C1_{t-1}) = (1+\delta)u'(C1_t)\, [Y1_t + (1+r)^{-1}Y2_{t+1}] \qquad (49)$$

which is different from (44). In this first case, we have observed that the inclusion of an overlapping generations model with intergenerational altruism can lead to divergence between individual and social optimal decisions. We have also observed that both decisions can differ from the decision indicated by the conventional application of discounting (condition (46)), which does not take into account who enjoys consumption but only considers the time distance from the moment of evaluation.

6.2.3. Investment by a young individual that yields benefits to his/her descendant of the first future generation

In this case, we assume that the investor, belonging to generation t, can transfer consumption to his/her descendant through an investment project that yields benefits in the

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[14] For the sake of simplicity, in this analysis we assume that the discount rate used in the NPV is the interest rate r. The qualitative conclusions would not change with respect to the case that we used the time preferences.

two following periods.

The budget constraints on the individual in generation t are:

$$C1_t = w_t - b_t - s_t + Y1_t(b_{t-1}) \qquad \text{(first period constraint)} \qquad (50)$$

$$C2_{t+1} = (1+r)s_t + Y2_{t+1}(b_{t-1}) \qquad \text{(second period constraint)} \qquad (51)$$

where b_t are the resources that the individual of generation t devotes to the project whose benefits are enjoyed by his/her heir; $Y1_t(b_{t-1})$ and $Y2_{t+1}(b_{t-1})$ are the consumption flows that he/she receives from the investment b_{t-1} transferred by his/her parent. The investment b_t yields the consumption flows $Y1_{t+1}(b_t)$ and $Y2_{t+2}(b_t)$ that his/her descendant receives.

The individual maximization program is:

$$\max_{s_t,\, b_t} \quad V_t + \delta V_{t+1} \qquad \text{s.t. (50) and (51)}$$

This includes the valuation that the individual of generation t has of the different flows of consumption that are directly modified by the investment and which affect his/her utility. These are the valuations of his/her own (V_t) and his/her descendant's (δV_{t+1}) consumption.

First order condition with respect to s_t:

$$u'(C1_t) = (1+s)^{-1}(1+r)u'(C2_{t+1}) \qquad (41)$$

First order condition with respect to b_t:

$$u'(C1_t) = \delta[u'(C1_{t+1})Y1_{t+1} + (1+s)^{-1}u'(C2_{t+2})Y2_{t+2}] \qquad (52)$$

The savings condition (41) remains unchanged. The left-hand side of the investment condition (52) shows the cost in terms of utility involved in an additional sacrifice of consumption during the first period of life. The right-hand side shows the increase in utility yielded by the increase in consumption of the heir caused by the increased investment in an additional unit.

Taking condition (41) one period forward, and substituting in (52) we obtain:

$$u'(C1_t) = u'(C1_{t+1})\delta[Y1_{t+1} + (1+r)^{-1}Y2_{t+2}] \qquad (53)$$

The different consumption possibilities (considered using marginal utilities) as well as the altruistic parameter have a very important role in the individual’s investment decision [15].

$$1 = [u'(C1_{t+1})/u'(C1_t))\delta(Y1_{t+1} + (1+r)^{-1}Y2_{t+2}] \qquad (54)$$

If we assume that $u'(C1_{t+1}) = u'(C1_t)$:

$$1 = \delta[Y1_{t+1} + (1+r)^{-1}Y2_{t+2})] \qquad (55)$$

This condition contrasts with the NPV criterion, where a constant time discount is applied without considering who enjoys the flows of consumption. The NPV states that the investment is profitable if the benefits are higher than the costs, which are both only weighted using the time discount factor. In this case, according to the NPV, it is profitable to invest until the next equality is achieved:

$$1 = (1+r)^{-1}Y1_{t+1} + (1+r)^{-2}Y2_{t+2} \qquad (56)$$

In the investment under consideration, if $\delta > (1+r)^{-1}$ then the optimal decision of the individual in the presence of altruism is more generous to the heir than the NPV criterion. Taking into account that each period represents half of an individual’s life span, it is not very daring to think that $(1+r)^{-1}$ is lower than δ.

The social maximization program is:

$$\max \quad (1+\delta)V_t + (\delta+\delta^2)V_{t+1} \qquad \text{s.t. (50) and (51)}$$

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[15] The condition can also be expressed in function of the marginal utilities of consumption for the first period of life as we assume that the allocation of consumption along the life-span follows the optimality condition (41).

b_t

The investor's consumption appears twice because it affects the utility of his/her parent (δV^t), an older individual at the time the investment started. The consumption of the heir appears with two weights, one for the investor (δV_{t+1}) and other for the investor's parent ($\delta^2 V_{t+1}$) consideration. The valuation of the consumption of the ascendant of the generation t-1 (V_{t-1}) is not included in the program because it is not directly affected by this investment.

First order condition with respect to b_t:

$$(1+\delta)u'(C1_t) = (1+\delta)\delta[u'(C1_{t+1})Y1_{t+1} + (1+s)^{-1}u'(C2_{t+2})Y2_{t+2}] \tag{57}$$

$$u'(C1_t) = \delta[u'(C1_{t+1})Y1_{t+1} + (1+s)^{-1}u'(C2_{t+2})Y2_{t+2}] \tag{58}$$

The investment condition is identical to (52), so in this case, social and individual optimal levels of investment are the same and both differ from the NPV.

In this second case we have seen that even when a structure of overlapping generations and altruistic considerations is included in the analysis, it may be that individual and social optima of intergenerational projects are the same. However, it is not legitimate to generalize this result and to assert that social and individual optima are always the same, and even less so to assert that methods (such as the NPV), which only consider the flows of consumption by the time discount of present generations, lead to optimal decisions regarding the level of intergenerational investment, as some authors do with similar models[16]. In the investment in this example, the negative effect that the decrease in the consumption of the investor has on his/her ascendant (an individual present in today's society) compensates for the positive effect caused by the consumption of the heir of the investor (first future generation) in the social welfare function.

The result of this second case is due to the particular characteristics of the investment under consideration, but it cannot be generalized to all intergenerational investments. In fact, one of the main results of incorporating different generations and intergenerational altruism in the analysis is the divergence that might arise between social and individual optimal levels of intergenerational investments, as we have previously seen.

6.2.4. Investment of an old individual that yields benefits to his/her grandchild, member of the first future generation

In the previous case, an investment taken by a young individual benefited his/her heir. Let us assume now that it is the old individual in t (generation t-1) who undertakes the investment enjoyed by his/her grandchild.

If the other circumstances are unchanged, the budget constraints of the investor in generation t-1 are as follows:

$$C1_{t-1} = w_{t-1} - s_{t-1} + Y1_{t-1}(b_{t-2}) \qquad \text{(first period constraint)} \tag{59}$$

$$C2_t = (1+r)s_{t-1} - b_t + Y2_t(b_{t-2}) \qquad \text{(second period constraint)} \tag{60}$$

where b_t is the investment that the individual of generation t-1 gives to his/her grandchild, member of generation t+1; $Y1_{t-1}(b_{t-2})$ and $Y2_t(b_{t-2})$ are the flows of consumption from the investment that the individual receives from his/her grandparent. The investment b_t yields the flows $Y1_{t+1}(b_{t-2})$ and $Y2_{t+2}(b_t)$ consumed by the grandchild of the investor.

The maximization program of the individual of generation t-1 is:

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[16] See e.g. Hultkrantz (1992), who identifies the social welfare function with the utility function of one member of the present generation, ignoring the point of view of the other present individuals. This leads, of course, to the coincidence between the social and the individual optimal investments considered in his work.

$$\underset{b_t,\ s_t}{\text{Max}}\ V_{t-1} + d\ V_t + \delta^2 V_{t+1} \qquad \text{s.t. (59) and (60)}$$

The project only modifies the consumption of the investor and his/her descendant of future generation t+1. We can thus obviate the valuation of the consumption of the descendant of generation t ($d\ V_t$) as well as the valuation of the consumption of the other descendants.

First order condition with respect to b_t:

$$(1+s)^{-1}u'(C2_t) = \delta^2\,[u'(C1_{t+1})Y1_{t+1} + (1+s)^{-1}u'(C2_{t+2})Y2_{t+2}] \tag{61}$$

The savings condition (41) does not change. Combining it with (61) we obtain:

$$(1+r)^{-1}u'(C1_{t-1}) = u'(C1_{t+1})\delta^2[Y1_{t+1} + (1+r)^{-1}Y2_{t+2}] \tag{62}$$

$$1 = H\delta^2[Y1_{t+1} + (1+r)^{-1}Y2_{t+2}] \tag{63}$$

Where $H = [u'(C1_{t+1})(1+r))/u'(C1_{t-1})]$

Again, we obtain a condition depending on both the different marginal utilities of consumption and the altruistic parameter δ, which shows the positive effect of the descendant (grandchild) on the welfare of the investor. It is easy to see that this condition differs from the NPV. According to the NPV criterion, it is optimal to invest up to the point that the next equality is achieved:

$$1 = (1+r)^{-1}\,Y1_{t+1} + (1+r)^{-2}Y2_{t+2} \tag{64}$$

where the weights given to the different consumption flows do not consider who enjoy them but only when are they enjoyed.

The social maximization program is:

$$\underset{b_t}{\text{Max}}\ V_{t-1} + (\delta + \delta^2)\,V_{t+1} \qquad \text{s.t. (59) and (60)}$$

The weight given to the consumption of the descendant of generation t+1 is higher than in the individual program. This is because both the consideration by the parent (δV_{t+1}) and the grandparent ($\delta^2 V_{t+1}$) are included in the social valuation. Both of them are present in the society taking the decision and are thus part of the social welfare function.

First order condition with respect to b_t:

$$(1+s)^{-1}u'(C2_t) = (1+\delta)\delta[u'(C1_{t+1})Y1_{t+1} + (1+s)^{-1}u'(C2_{t+2})Y2_{t+2}] \tag{65}$$

If we introduce the savings condition (41) we get:

$$(1+r)^{-1}\,u'(C1_{t-1}) = u'(C1_{t+1})(1+\delta)\delta[Y1_{t+1} + (1+r)^{-1}Y2_{t+2}] \tag{66}$$

$$1 = H(1+\delta)\delta[Y1_{t+1} + (1+r)^{-1}Y2_{t+2}] \tag{67}$$

In the condition of the individual optimal level of investment (63) the weight given to the consumption of the individual of future generation t+1 with respect to the weight given to the sacrifice of an additional unit by the individual of generation t-1 was $H\delta^2$. In the social case (67) this weight is clearly higher, $H(1+\delta)\delta$. This is due to the fact that in the social valuation, the effects that the project causes on the utilities of all present individuals are included and not only the effects on the utility of the investor, as occurs in the individual case.

In general, the optimal social decision with respect to the level of intergenerational investment derived from a social welfare function including altruism is more generous to future generations than the optimal decision from the individual point of view. Furthermore, both of them differ from the NPV and very probably give more weight to consumption by future generations[17] because the positive influences of their consumption on the utility of their ascendants present in current society are taken into account. However, the NPV only considers the future through an arbitrary extension of the time preferences of present generations, thereby applying a negligible weight to future flows of consumption.

It is not necessary to repeat the entire analysis to affirm that the divergence is larger in the case of public goods, where the difference between the effects taken into account by an individual and the effects that enter into the social consideration are much larger.

6. 3. Some comments on optimality in intergenerational investments

The use of an overlapping generations model has allowed us to introduce the existence of different generations and the interrelationships between their welfare, including altruistic preferences, into the analysis. We have thus been able to consider the problem of intergenerational allocation without avoiding the issue of the individuals' intertemporal allocation of consumption, as do most studies on the subject. Both issues are part of the intertemporal allocation of resources and must be taken into account in order to perform an appropriate analysis of it.

After considering different generations and intergenerational altruism, we have concluded that the optimal decisions of investment derived from individual and social preferences imply some factors that are not taken into account in usual calculations. Both in the individual and social decisions, the weight given to each consumption depends on who receives it and not only on the time discount of present generations, as is the case with conventional methods such as the NPV. Under the conditions of optimality derived in this section, the time discounting for the different flows of consumption is applied from the point of view of the individuals who receive them. These valuations are then weighted according to how they affect individual or social welfare, taking into account the altruistic preferences of individuals.

The optimal social decision regarding intergenerational investments is generally more generous with future generations than the individual one. This is due to the fact that in social decisions, all the effects that investments have on the utilities of the individuals within society are taken into account, and not only the effects on investors. Furthermore, both are very likely to be more favorable to future generations than conventional methods such as the NPV. These methods take into account all the flows of consumption, applying only the time discounting of present individuals and thus they ignore intergenerational allocation. It seems appropriate to modify the investment management and evaluation methods usually applied in intergenerational issues, as is the case with many environmental projects. In this regard, the application of the MGNPV proposed in the previous section would lead to the weighting of future consumption, taking into account the preferences regarding the consumption of future generations. This will help to avoid the negligible weight usually given to future generations. The application of conventional discounting is misleading with regard to the true preferences of society and could lead to investment well below the optimal level in many environmental and infrastructure projects.

7. CONCLUSION

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[17] In this specific case, assuming that the different generations have the same marginal utility of consumption, this is true if $(1+\delta)\delta$ is higher than $(1+r)^{-1}$.

The set of economic instruments for internalizing externalities and providing collective goods are effective to a more or less satisfactory extent for solving the environmental problems affecting present generations. However, these instruments are inappropriate for considering the externalities that present generations cause to future generations and for preserving intergenerational goods.

Obviously, if the world ended with present generations, problems such as climate change or the loss of biodiversity would merit much less attention. The reason for this is simple - the costs to present generations are relatively small, while it is to be expected that they are very important for future generations.

It should be noted that a necessary condition for internalizing intergenerational externalities is to have a system which allows future generations to have a part of the property rights and to be able to manage and negotiate with them without any limitations other than those governing the behavior of the present generation. For the moment, there is no institution which could transfer property rights to future generations. Efforts towards environmental management according to conventional economic theory therefore only work to the benefit of the present generation, in as far as they do not consider the interests of future generations.

This is an economic problem, but only in part, because any solution to it requires a new institutional framework. It is necessary to create new institutions which allow future generations to

a) Have their rights over natural resources and the environment recognized.

b) Be able to negotiate their property rights in the market with the same rights and possibilities as present generations.

c) Have access to administrative and law systems

d) Have a voice and vote in the political system.

To conclude, we feel that the main problem is the conflict of interests between present and future generations. The consequences of this conflict from a distributive perspective have been studied (see e.g. Lind, 1995) However, the impact from an allocative point of view have been studied to a lesser extent [18] and for this reason, we have devoted the second part of our study to this important problem.

Research has focused on the search for a satisfactory solution to the consideration of future generations in project and policy appraisal. Conventional cost-benefit analysis loses its legitimacy in the intergenerational context. An appropriate treatment of intergenerational problems needs to overcome the strong limitations of conventional economic analysis, such as the very unequal distribution of rights or the infinite substitution possibilities it assumes. The paper has presented an alternative evaluation process consistent with the sustainability requirement in which the right of future generations to enjoy a non-diminished resource capacity is recognized. The consideration of preferences over the consumption of future generations has led us to recommend a new valuation method, the multigenerational net present value, for considering the impact on each generation by means of the correct intergenerational weight. Finally, analysis of various possibilities for intergenerational investments has shown that conventional methods do not take into account preferences for the consumption of future generations in an appropriate manner, which reinforces the need

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[18] In Pasqual and Souto (2003) the relationships between present and future generations are analyzed, taking into account both the distributive and the allocative effects.

to apply the new methods in order to consider the consumption flows in each generation adequately.

REFERENCES

Barrett, C.B. (1996). Fairness, stewardship and sustainable development. *Ecological Economics, 19*, 11-17.

Barro, R.J. (1974). Are Government Bonds Net Wealth? *Journal of Political Economy, 82,* 1095-117.

Bator F. M. (1958). The anatomy of market failure. *Quarterly Journal of Economics, 72,* 358.

Baumol, W. (1952). *Welfare State Economics and the Theory of State.* Cambridge: Harvard University Press.

Bellinger, W. K. (1991). Multigenerational value: modifying the modified discount method. *Project Appraisal, 6*, 101-108.

Bird, P., J. W. N. (1987). The transferability and depletability of externalities. *Journal of Environmental Economics and Management, 14,* 54-57.

Bromley, D.W. (1989). Entitlements, missing markets, and environmental uncertainty. *Journal of Environmental Economics and Management, 17*, 181-194.

Broome, J. (1992). *Counting the Costs of Global Warming*. Cambridge: White Horse Press.

Buchanan, J., & Craig, W. (1962). Externality. *Economica, 29*, 374.

Coase, R. H. (1960). The problem of social cost. *Journal of Law and Economics, 3,* 1-44.

Collard, D. (1981). *Altruism and Economy.* Bath: The Pitman Press.

Costanza, R. (1994). Three general policies to achieve sustainability. In A. Jansson, M. Hammer, C. Folke, & R. Costanza (Eds.), *Investing in Natural Capital: the Ecological Economics Approach to Sustainability* (pp. 392-407). Washington DC: Island Press.

Costanza, R., & Perrings, C. (1990). A flexible assurance bonding system for improved environmental management. *Ecological Economics, 25*, 55-57.

Doeleman, J. A. (1988). Social Determinism, technology and economic externalities. In C. Tisdell, & P. Maitra (Eds.), *Technological Change, Development and the Environment: Socio-Economic Perspectives* (pp. 298-321). London and New York: Routledge.

Howarth, R. B., & R. B. Norgaard. (1995). Intergenerational Choices Under Global Environmental Change. In D.W. Bromley (Eds.), *Handbook of Environmental Economics* (pp. 111-138). Oxford: Blackwell Publishers.

Howarth, R. B. (1997). Sustainability as opportunity. *Land Economics, 73,* 569-579.

Hultkrantz, L. (1992). Forestry and the bequest motive. *Journal of Environmental Economics and Management, 22,* 164-77.

Katz, M. L., & Shapiro, C. (1985). Network externalities, competition and compatibility", *American Economic Review, 75,* 424-440.

Markandya, A., & Pearce, D. (1988). Sustainable future. Natural environment and the social rate of discount. *Project Appraisal, 3,* 2-12.

Mishan, E. J. (1971). The postwar literature on externalities: An interpretative essay. *Journal of Economic Literature, 9*, 2-3.

Neumayer, E. (1999). *Weak versus Strong Sustainability.* Exploring the Limits of Two Opposing Paradigms. Cheltenham: Edward Elgar.

Nijkamp, P., & Rouwendal, J. (1988). Intergenerational discount rates in long-term plan evaluation. *Public Finance/Finances Publiques, 43*, 195-211.

Norton, B. G. (1995). Evaluating ecosystem states: two competing paradigms. *Ecological Economics*, *14*, 113-27.

Ocaña, C., & Pasqual, J. (1994). Environmental costs of residuals: a characterization of efficient tax policies. *Revista Española de Economía, Special Issue: Recursos naturales y medio ambiente*, 51-59

Padilla, E. (2002). Intergenerational equity and sustainability. *Ecological Economics, 41*, 69-83.

Page, T. (1983). Intergenerational justice as opportunity. In D. MacLean, & P. G. Brown (Eds.), *Energy and the Future*. Totowa, NJ: Rowman and Littlefield.

Page, T. (1997). On the problem of achieving efficiency and equity, intergenerally. *Land Economics, 73*, 580-596.

Pasqual, J. (1999). *La Evaluación de Políticas y Proyectos*. Barcelona: Icaria Editorial and Universitat Autònoma de Barcelona.

Pasqual, J., & Riera, P. (2004). Underground land values. *Land Use Policy*, *forthcoming*.

Pasqual, J., & Souto, G. (2003). Sustainability in natural resource management. *Ecological Economics, 46*, 47-59.

Pigou, A. C. (1920). *The Economics of Welfare*. London: Macmillan.

Price, C. (1993). *Time, Discounting and Value*. Oxford: Blackwell.

Price, C. (1996). Discounting and project appraisal: from the bizarre to the ridiculous. In C. Kirkpatrick and J. Weiss (Eds.) *Cost–Benefit Analysis and Project Appraisal in Developing Countries.* Cheltenham: Edward Elgar.

Samuelson, P. A. (1954). The pure theory of public expenditure. *Review of Economics and Statistics, 36*, 387-389.

Samuelson, P. A. (1958). An exact consumption-loan model of interest with or without the social contrivance of money. *Journal of Political Economy, 66*, 467-482.

Thompson, E. (1966). A Pareto optimal group decision process. In G. Tullock (Ed.) *Papers on Non-Market Decision Making* (pp. 133-140). Charlottesville: University of Virginia.

Uhlaner, C. J. (1989). Democracy and participation: incorporating sociability into a rational action. *Public Choice, 62*, 253-285.

World Commission on Environment and Development (WCED). (1987). *Our Common Future*. Oxford: Oxford University Press.

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