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INTERGENERATIONAL EQUITY IN NATURAL RESOURCES MANAGEMENT

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1. Introduction

The treatment of the natural capital in the design and evaluation of policies is an important problem which is currently in the fore. That is due both to the fact that the existing theory is far from satisfactory and to the relevance of this issue on future generations. The key question is how the available resources should be distributed among generations. Different authors take up distinct stances regarding this question. On one hand, some authors maintain that all the natural goods are exclusively own by present generations. This position is reflected in statements like the following: "*past generations are not here any long, and those that have to come, they will come because we want them to come. Plainly speaking, the world belongs to those who live in it now and to nobody else*"[1].

On the other hand, there is a stream of thought which holds that future generations have certain rights on the existing natural capital and that, consequently, we have to manage somehow that present generations (PG) respect these rights.

From the first group viewpoint, there are no distributive or efficiency problem, since resources have to be used according to the convenience of present generations members. By contrast, the second group claims that there is an important problem: how to define future generations (FG) rights on the currently available natural capital, how to allocate it and how to guarantee both the preservation and the proper management of its corresponding part.

2. Two ways of addressing the problem.

Generally speaking, there are two possible ways of facing the intergenerational distribution of resources:

a. On one side, there is the "individualist approach"(Kirsh, 1986). The reason of this name is that the analysis is based on individuals instead that on generations as a collective body. Each individual aims to maximise his/her welfare function, taking into account not just his/her own satisfaction, but his/her descendants' welfare. Obviously, these computations change for each individual, because each one has his/her own preferences. In this context, the intergenerational distribution problem does not arise, since it is solved by each individual when he or she takes his/her own allocative decisions between consumption and savings.

b. On the other side, there is what we could call "collectivist approach" which regards future generations consumption as a public good (Mueller, 1974). Individuals, when take their own consumption decisions, have to choose somehow between own consumption and consumption of all the members of FG. Their decision will not be to increase their savings, since they know that if they act on their own they will not improve the global welfare of FG. However, they would be willing to accept a tax which also accrued to all the members of their own generation, and which raised funds that were earmarked for FG.

It is obvious that the individualist approach does not solve the intergenerational equity problem and that it just denies its existence. Nevertheless, the huge debate that has arisen in the whole society and which it is not constrained to the economic field, but that embraces other disciplines like sociology, government policy, philosophy or biology, should be enough to show that this is not the proper approach. Another irrefutable proof that the problem exits is that many natural resources -the air, the ozone layer, etc.- have clear public goods features

[1] Mas-Colell, (1994), p.200

and, therefore an individual rational behaviour can never lead to an efficient -neither equitable- allocation, but it will hopelessly yield to what Hardin called "the tragedy of the commons"[2]. Not even in the case of private natural goods -like, for instance, the forest- can we take the efficiency for guaranteed.

The basic premise of those economists that participate in the debate about the intergenerational distribution of natural resources is the need to fulfil the **sustainability requirement**[3]**.** The first difficulty of this analysis is to know what this word exactly means. Pezzey (1989) recollected sixty-one definitions of sustainable development and, since then almost a decade has gone by. Clearly the first question we have to address is how to find the solution to a problem we have not clearly defined. To put it another way, if there is no agreement about what sustainability is, we will hardly reach an agreement about the best way to manage natural resources to achieve it .

According to Pearce and Turner (1990) sustainable development means keeping always constant the stock of available natural resources and not allowing it to decrease in any case. That leads to the application of the Pareto principle among generations[4]. Underlying this statement there are the following assumptions:

- First, either sustainable development is not measured in per capita terms or it is considered that population will remain constant. If world population grows, keeping the current natural capital stock constant does not guarantee that future generations can enjoy, at least, the same welfare level. Is that sustainability?

- In addition, natural goods are regarded as perfect substitutes among them. That is to say, when a non renewable good -oil- is consumed, an amount equivalent to the value of this resource should be invested in alternative natural goods. However, it is not clear that the substitution of oil for trees, for instance, is an ideal solution to maintain future generations welfare. Furthermore, we should establish what we mean when we use the expression "natural goods". The most widespread definition of natural goods describes them as all the goods that are available to mankind as a "Nature present"-rivers, forests, the sea, animals, etc.- but also those which could be called "natural bads"as plagues, for instance. Inmediately a question arises: when we fumigate a house, when we try to eliminate the rats from the underground net or when we simply use a domestic insecticide, are we destroying part of the natural resources stock?. Does that mean that we have to plant a tree to compensate this loss? The answer would be affirmative if we adopted a pantheist attitude and considered all the species equally valuable.

- Finally, there is the underlying assumption that the current stock is the social optimum and that, consequently, it should be preserved, what is not necessarily true. Gómez (1994)[5] argues that this proposal is justified by the difficulties in identifying the social optimum; that is to say, as we do not know which is the idoneous amount, they propose to assume that it is the existing one. Thus it is practically impossible to determine the optimal social amount for the overall natural resources without introducing subjective judgement values. Nevertheless, if we decided to deal with every resource or group of resources individually,

[2] See Azqueta & Ferreiro (Eds) (1994)

[3] See, for instance, Mikesell (1989); Pearce & Turner (1990); Pearce & Markandya (1994).

[4] In fact the Pareto principle is a stronger constraint, since if it was applied among generations it would imply to keep constant the stock of all the goods, and not just the natural resources.

[5] In Azqueta & Ferreiro (Eds) (1994)

instead of dealing with all of them together, the situation would be different. That would simultaneously solve what we called the "natural bads" problem.

3. The available natural capital stock: identification and classification

To address the problem of the distribution between PG and FG is necessary first an identification and operative classification of resources. There are many definitions of natural resources, but the most general one identifies as natural resources those goods that are available to mankind as a "Nature present". It is obvious that this definition is broad enough to include very diverse goods.There are many classifications of natural resources. However, taking into account the problem we are concerned about -the distribution among generations- we are mostly interested in the following categories, since the treatment of each of them has its own features:

a) **Free goods**, or goods whose comsumption does not generate any opportunity cost to the other possible users- including, of course, the future generations. Examples are the gravity force, the moon or the sun energy.

b) **Non renewable goods**, are those goods which have a limited existence in the planet, but they can be kept through time without changing its quantity or quality, that is to say, it is possible to store them at a zero price through an unlimited period. This is basically the case of mineral resources. Nevertheless, it is necessary to distinguish among different sorts of non renewable resources depending on whether its consumption leads to destruction and whether this are total or partial.

* **durable goods**: it refers to those goods whose consumption implies to posses them and/or to admire them and which are not destroyed. It is the case of precious metals like gold, gems (emeralds, diamonds, etc.), art pieces (piramids, cathedrals, cave paintings, etc) or arqueological remainings.

* **non-durable goods**: by constrast with the former category, non-renewable non-durable goods are destroyed when people consume them. However, it is important to distinguish whether it is possible to recycle them, what would make destruction not completely irreversible:

  - **recyclable goods**: it refers to those minerals which are not completely destroyed when they are used and which can be recycled if certain cost is assumed (iron, copper, aluminum, etc.)

  - **non-recyclable goods**: it refers to fossil fuels (oil, coal, natural gas) which are completely and immediately destroyed when they are consumed.

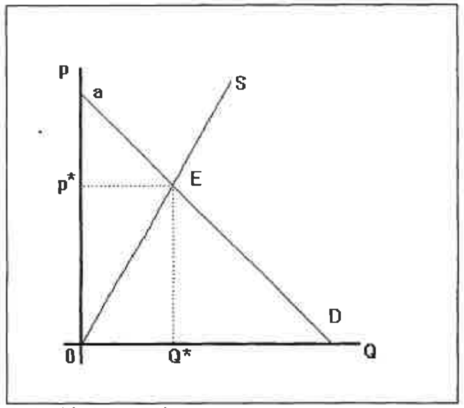
c. **Renewable goods**: it refers to those goods that can be consumed, but can also be renewed, what enables the consumption of future generations of these goods. We can classify those goods in the following categories:

* **Biological**: it refers to those goods whose consumption implies the destruction of part of them, but which reproduce quickly at its own biological cycle, so that the available amount does not vary. It is obvious that if we consume them at a rate higher than its own renewal rate, we will destroy the resource. Examples are forest, fishing grounds or aquifers.

* **Non-biological**: This group includes those resources that are sometimes classified as "environmental goods", i.e., the air, the soil, the ozone layer, the sea, etc. These goods used to be free goods, but they no longer belong to this category since its consumption can damage the rest of users, that is to say, it can pollute. This kind of goods have a limited capacity of self-regeneration when they get destroyed. Thus, ozone layer, for instance, is able to bear certain polluting gas emissions in the atmosphere, since it automatically self-regenerates. Nevertheless, if the self-regeneration capacity of these resources is overcome, many grave problems arise which can affect the welfare of both the FG and the PG.

Once we have identified and classified the natural resources, the next step is to know its value. The common measurement unit can only be the monetary unit, that is to say, we have to assign a price to each of them. In fact, the solution is not so easy, first, because of the difficulty of finding this price and, second, because this is not an exact measure of the welfare generated by those resources. As we can see in Figure 1, taking into account this price, the value we obtain will only be part of the area that it is below the corresponding demand curve (the 0p*EQ* area), ignoring the rest (p*aE area), which is also part of the overall social value. Consequently, when we conclude that the value of a resource equals x$, that does not mean that society is indifferent between this resource and this amount x, because what is valid for small variations can not be extrapolated to significant variations.

Figure 1



Total social value = 0aEQ* area
Price = 0p*EQ*

Furthermore, there is an added difficulty; the fact that the price of a natural resource depends to a large extent on the available stock of other resources. For example, a single forest in a country would be priced much higher than if there were one hundred more forests in the same country. Besides, its price also would be influenced by the existence of other natural goods (prairies, farms, etc.) and other no natural resources.

In order to undertake a more detailed analysis, it is necessary to limit it to a concrete spatial context. This can be a country or a region. Nowadays, a global action is impossible due basically to political and economic problems. However, this aspect could be improved.

When considered at the national level, for example, the basic matter consists in determining which is the total wealth of the nation. This wealth is measured in monetary values, and will be made up by the sum of the monetary values of the natural resources and the rest of resources. First of all, it is necessary an inventory of available natural goods. Then, they would be valued by the assignment of a price to each of them, then obtaining an overall monetary value the stock of natural resources by one hand and another overall value for the rest of resources. Nevertheless, this does not mean that society is indifferent between the stock of natural resources and the amount of money assigned to them as its total value. The reason is that when we reduce the initial stock, the value for the rest will rise. It is for that reason that there is not "enough money in the Earth to buy the Earth".

At the international level, things are even much more complicated due to the existence of a serious conflict of intragenerational equity, that existing between poor and rich countries. Basically, the problem is the following one. The developed countries have relatively high life standards. To achieve them they have sacrificed natural resources (inside and outside their borders) increasing the stock of non natural resources. On the other hand, poor countries wish to obtain the same quality of life following the same path. In other words, diminishing their stock of natural resources (forests, clean air,...) in order to increase the rest of resources (TVs, cars,...). Citizens of rich countries would prefer that developing countries keep their stock of natural capital (sustainability) in order to go there on holidays, or to maintain a certain natural equilibrium. But in contrast, they do not seem willing to pay for that use, contributing to the increase in quality of life in those countries to prevent them from being forced to destroy their natural resources. The problem at stake is that natural goods are public goods, while the majority of the rest of resources are private. This means that maintaining natural capital in less developed countries benefit everybody, while a car only benefits directly its owner. That is to say, rich countries do not share costs of maintaining natural capital but only its benefits. Then we are facing the difficult problem of how to take steps to arrange public goods and externalities.

Summarising, the first step to be undertaken in order to reach an optimum management of natural resources would be the elaboration of an inventory or check list, that is to say, the identification, classification and valuation of the existing stock of natural resources, bearing in mind all the difficulties this task involves. To do so this paper proposes to start with the election of a certain spatial area. Thus, the difficulty of inventoring is smaller. When the policy is not made on the basis of prices, then the economic globalization does not prevent us from obtaining successful results in a reduced area.

4. The distribution of property rights (PR) of natural resources among generations

In order to correctly treat the problem of the allocation of natural resources we need to start from the previous knowledge of the theories on externalities and public goods. In particular for the case of the intergenerational allocation, it is very useful to get to characterize the consumption of a certain good, both within the same generation and among different ones. To do so, and following Pasqual (1991), goods can be featured according to an consumption efficiency factor K , where:

$$K = \frac{\text{initial endowment decrease}}{\text{consumed amount}}$$

It results:

K	Type of good	Characteristics
K < 1	hyperpublic	The available amount increases when consuming the good
K = 0	pure public	The available amount remains constant after consuming the good
0 < K < 1	local public	The available amount diminishes when consuming the good, but less than proportionally to the consumed amount
K = 1	pure private	The available amount diminishes exactly in the consumed amount
K > 1	hyperprivate	The available amount diminishes more than proportionally to the consumed amount

When natural resources have characteristics of pure public goods among generations, that is, when the consumption done by PG does not cause a decrease in its available amount for FG, there is no intergenerational conflict. The problem arises when this condition does not hold, when natural goods behave rather like local public, private or hyperprivate goods among generations. This fact implies that the consumed amount by present individuals causes a certain opportunity cost for their descendents. To solve this problem in these cases, there is a need to define the property rights (PR) of resources among the different generations, that is, to decide which part of the resource belongs to each of them.

Now the possible alternatives for the hypothetical case of a good the initial value of which is Q_0 is examined, a good that could be thus exploited and produced at a profitability rate of q per cent. The present generation is composed by n_0 individuals and the first future generation by n_1 individuals. That means that the sustainability condition in a broad sense demands de following condition:

$$\frac{Q_0}{n_0} = \frac{Q_1}{n_1} \qquad [1]$$

Q_1 is the value of the resource in period 1, when the following lives. The expression [1] is equivalent to the following:

$$Q_1 = \alpha Q_0 \qquad [2]$$

where $\alpha = n_0 / n_1$.

To simplify the analysis, it is assumed that the population remains constant throughout time, that is, α=1. And as a consequence, $Q_0 = Q_1 = Q$, that is, sustainability is reached by keeping constant the initial stock of the resource.

We basically face the following possibilities regarding the definition of PR on natural resources:

- Scenario I: property rights exclusively belong to present generations
- Scenario II: they exclusively belong to future generations
- Scenario III: they are somehow distributed between present and future generations

Scenario I: the PR are in hands of PG, who can exploit the resource as they need. From the total wealth obtained [$Q(1+q)$] from the initial amount of the resource (Q) they will consume a certain proportion h ($0 < h < 1$) and bequeath their descendants the rest, so that the amount of the resource available for FG is given by [$(1-h)Q(1+q)$]. In particular, PG would enjoy the right to consume all available resources (h=1). The consequent allocation would then be:

$$PG = hQ(1+q) \quad [3]$$
$$FG = (1-h)Q(1+q) \quad [4]$$

Scenario II: the PR exclusively belong to FG, but PG have the right of using and exploiting the resource, otherwise the problem would be a *reductio ad absurdum*, since there would never be consumption due to the owners would always be FG, and that would happen infinite times. As a result, we assume that PG can exploit the resource and use the obtained rent [Qq], that could be totally or partially consumed [hQq], leaving for FG the initial wealth [Q], and the inheritance they receive from PG [$(1-h)Qq$]. Mathematically,

$$PG = hQq \quad [5]$$
$$FG = Q + (1-h)\,Qq \quad [6]$$

Scenario III: we consider that the PR are distributed in a way such that FG have a part p of the resource ($0<p<1$) and the rest ($1-p$) belongs to the FG. In this case, the PG consumption results from [$hpQq$], whereas the FG available consumption is given by the expression [8], where the first term is the part of the resource that belongs to them and the second, the PG inheritance.

$$PG = hpQq \quad [7]$$
$$FG = (1-p)\,Q + (1-h)\,pQq \quad [8]$$

If we assume that all the generations have the same right on the initial resource - i.e., PR are equally distributed- the percentage of the resource that corresponds to PG is given by $p=n/g$, where n is the number of PG and g the number of FG. But if the number of FG is large -what it seems a reasonable assumption- p will tend to 0, what is equivalent to consider that all the PR are on FG hands; that is to say, we are again in Scenario II, since the allocation is:

$$PG = hQq \quad [7'] = [5]$$
$$FG = Q + (1-h)\,Qq \quad [8'] = [6]$$

It is important to point out that Scenarios II and III fulfil the sustainability principle, strongly demanded in most of the environmental economic literature. The PG are entitled to exploit resources and to keep the obtained rent, provided it does not result in an opportunity cost which accrue on FG, that is to say, the initial wealth has to increase or remain constant.

The next generation, in their turn, will have to do the same, and that holds for the following ones. The initial wealth Q will always be available and the only thing that is consumed in each period is a part -smaller of larger[6]- of the exploitation rent (hQq). By contrast, Scenario I does not necessarily lead to the fulfilment of the sustainability requirement, since PG are allowed to consume as much quantity of the resource as they want, an even to exhaust.

There are different arguments to support the distribution of PR in one way or other. Defenders of the allocation in favour of the PG argue, for instance, that we can expect that technological progress enables the existence of perfect substitutes, or even that the change in relative prices leads to FG valuing these resources much less than PG[7]. If that was the case, the final result would be a decrease of social welfare - the PG sacrifice consumption which FG "despise". But, by contrast, it may happen that PG exhaust certain resources which FG consider very valuable, due to its scarcity, so they could say "when somebody thinks about that, is ashamed even of past generations"[8]. In any case, given that this alternative does not fulfil the sustainaibility requirement -which has been set as unavoidable- can not be considered correct.

From other authors point of view, the sustainability principle does not necessarily imply a distribution of the property of the resources[9] and, consequently, if the PG undertake the exploitation they should earmark some profits for the payment of the PR to FG. The problem would be, then, how to determine the amount to pay and, subsequently, how to accomplish this payment.

Summarising, once we have examined the three possible alternatives in the intergenerational distribution of natural capital PR (Table 1), we reach the conclusion that the most efficient solution -which also guarantees the sustainability- is to assign all the PR to the FG and to assign the exploitation and use rights to the PG.

[6] The percentage or the rent that is consumed in each generation depends - as we have already mentioned- on parameter *h*, which is reflecting somehow the preferences of one generation for its own consumption in relation to the consumption of next generations. That is to say, parameter *h* will depend on factors such as the level of overall available rent or the intergenerational discount tax.

[7] An example is the salt, which very highly valued in certain civilisations and was even used as a currency. However, if those civilisations decided to consume less to leave it to their descendants, they renounced to certain amount of welfare useless, since present generations assign a lower value to this resource.

[8] Plinio the Old (I century v.c 1993). Lapidario. Alianza Editorial, Madrid.

[9] Mikesell (1989)

Table 1

PR	PG Consumption	FG resources	Total available
PG (Scenario I)	$h(1+q)Q$	$(1-h)(1+r)Q$	$Q(1+q)$
FG (Scenario II)	hQq	$Q+(1-h)Qq > Q$	$Q(1+q)$
Distribution (Scenario III)	hQq	$Q+(1-h)Qq > Q$	$Q(1+q)$

The allocation of all the PR to the FG (Scenarios II and III) implies that PG are allowed to dispose of the resource and to keep the obtained exploitation rent. This arrangement guarantees the preservation of the initial wealth (Q)[10], what has the following implications:

a. It establishes a resources consumption constraint.

b. It implies that no generation is entitled to destroy resources, and, consequently, if they do it, they have to pay the cost of their action.

5. Non-renewable resources

As we have already seen, non-renewable resources are those resources that have a limited existence. However, when we study the intergenerational allocation of this kind of resources is important to take into account that their consumption does not necessarily imply their exhaustion, given that it is possible to re-use and to recycle them. Hence we have to do a more exhaustive classification and to treat them separately.

5.1. Durable goods: it refers to goods that have a private character within a generation - they just belong to certain individuals- but with a public character among different generations - because the consumption of the present generation does not decrease the available amount for future generations. Consequently, in general, the consumption of this kind of goods does not generate an opportunity cost for future generations, so the intergenerational redistributive conflict does not exist. Translating the problem in terms of PR is equivalent to assign all of them to FG, since PG can use the goods, but they are not entitled to destroy them, in order to guarantee the sustainability. In fact, it is probable that a small part of this sort of resources is lost from one generation to the other due to different problems. In this case, this lost part should be treated like a non-renewable non-recyclable good, given that the FG will not have it (it is a private good among generations).

[10] In the case of non-renewable goods (aquifers, forests, etc), PG can exploit them, provided they guarantee that the value of the resource will not decrease. By contrast, if the resource was not renewable (a coal mine, for instance) the PG would be entitled to exploit it, but they should invest part of the obtained profits in alternative capital goods which guaranted a wealth equivalent to the initial value of the mine for the FG.

5.2. Non-durable goods: in general, their consumption implies their destruction, although if it is possible to recycle the good, the recycling will not be complete. Summarising, they are private goods within a generation, which can be private goods among distinct generations - in case they can not be recycled- or public local goods among different generations if they can be recycled, because the available amount does not decrease in the same percentage than the consumed amount, but in a smaller one. If it is not possible to recycle, this cost will be exactly the value of the "in situ" resource value -before extracting and transforming it- whereas if the recycling is possible the opportunity cost that GP impose on FG is the difference between the recycling cost and the extraction cost. The question that arises in both cases is how to distribute this kind of goods among different generations.

If we want to fulfil the sustainability requirement, all the PR on resources have to be assigned to FG (Scenario II or III of Table 1). PG can exploit the resource if it is profitable to do it, but when they evaluate the profitability of the project, they have to take into account a new cost, the payment of the PR to the FG. To put it another way, part of the profits obtained in the exploitation will not be available for the PG consumption, but they should be earmarked for FG.

In order to determine the PR price it is necessary to recall the Table 1 conclusions, particularly Scenarios II or III, which leads to the efficient solution. For the case of a non-renewable resource -like, for instance an iron mine- the initial available wealth (Q) has to be expressed as the product of the shadow price of the "in situ" resource (p_s) multiplied by the available resource stock (X_d):

$$Q = p_S X_d \qquad [9]$$

On the other hand, the profitability of the exploitation of the resource (q in Table 1), assuming that all the available stock is extracted[11], would be given by:

$$q = \frac{Q' - Q}{Q} \qquad [10]$$

Where Q' expresses the value of the resource extracted once it has been transformed and traded in the market:

$$Q' = p_t X_d \qquad [11]$$

Where p_t is the shadow price of the resource once it has been transformed, i.e., taking into account the extraction cost[12] (C_e).

That is to say, if we exploited the resource we would obtain a final wealth of $Q(1+q)$, so that, applying the allocation rule of Scenarios II or III of Table 1, PG will be able to consume[13] qQ, whereas they will have to leave the amount Q at the FG disposal. Denoting with h the

[11] If the amount extracted (X_e) was lower than the overall available stock (X_d), the profitability of the exploitation would be computed as $q = [(p_t X_e)-(p_S X_e)]/(p_S X_e)$

[12] The recyclable amount has always to be strictly lower than the consumed amount. Put it another way, λ oscillate between 0 and 1 ($0 < \lambda < 1$).

[13] In fact, they would consume a part h of the available consumption (hqQ), leaving the rest [(1-h))qQ] in inheritance.

consumption percentage, the PR to pay will be given by the value of the consumed amount, that is to say:

$$PR = hQ = h\, p_s X_d \qquad [12]$$

Particularly, if PG consumed all the available resource (X_d), the PR price that PG would have to pay to FG is the overall value of the "in situ" resource:

$$PR = Q = p_s X_d \qquad [12']$$

Let's assume now that it is possible to recycle a part λ of the consumed amount, that is to say:

$$\text{recyclable amount} = \lambda\, h\, X_d \qquad [13]$$

Denoting the recycling cost with Cr, we can infer that the value of this amount once it has been recycled is given by:

$$\text{value recycled amount} = \lambda\, h\, X_d\ (p_t - Cr) \qquad [14]$$

And, consequently, the amount that the PG have to pay to the FG in terms of PR is given by the difference among the expressions [12] and [14]:

$$PR = h\, X_d\, [p_s - \lambda\,(p_t - Cr)] \qquad [15]$$

That is to say, the PG have to pay to the FG in terms of PR, the difference between the value of the consumed amount and the scrap value, which is given, in its turn, by the difference between the market price and the recycling cost. If the PG consumed all the amount initially available (h=1) the former expression would be simplified, being expressed like the difference between the initial value of the resource and the scrap value of the same once it has been used and recycled:

$$PR = X_d\, p_s - \lambda\, X_d\ (p_t - Cr)] \qquad [15']$$

Consequently, the problem of the intergenerational allocation of non-renewable non-durable resources- whether they are recyclable or not- is constrained to the non easy task of computing the shadow prices of each resource at the initial situation -before extracting them- and at the end- once they have been transformed and they are available for consumption. Although the shadow price concept is very simple, in practice, its computation is not so straightforward[14]. The idea is to determine the price that a resource would have in a perfectly competitive market or, what is the same, its marginal cost.

The question of how to transfer the PR payment to the FG is still unsolved. Most of the proposals in this sense[15] suggest the investment of this amount (Q) in renewable capital goods, so if investment was profitable -as it is reasonable to expect- the sustainability requirement would be largely fulfilled and FG would have a initial wealth higher than Q. However, the adoption of this kind of solution implies that resources are perfect substitutes among them, what it is not so clear. That is to say, there is no guarantee that FG will have the

[14] Halvorsen and Smith (1984) estimated the "in situ" shadow price of the mineral of gold from the canadian mines through the econometric estimation of the cost function of renewable inputs used in the extraction and transformation of mineral of gold in gold.
[15] See, for instance, Solow (1974), Hartwick (1977) or Mikesell (1989)

same level of welfare than PG if they find no oil but more fishing grounds. It is our contention that the idoneous solution would be to create several institutions which were in charge of controlling that the established PR are fulfilled and of managing in a more profitable way the corresponding capital in case that the PR were bought by PG. Those institutions would act as representants of FG as well. The question arises, then, of how to design them properly. This institutions have to be completely independent of the PG interests and to remain outside the conflicts that may affect its members, although, unavoidably, they would be formed by PG members.

6. Renewable resources

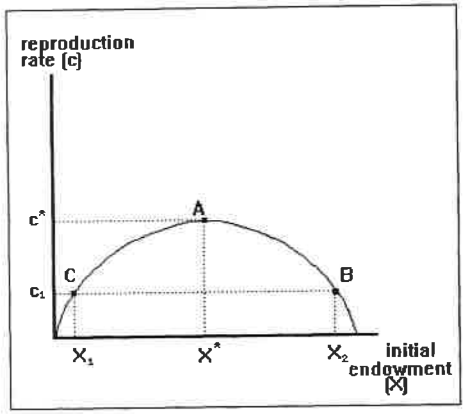
This is a rather different case from the one used in the previous section. With presence of renewable resources the ideas above mentioned can hardly be used, for instance in the case of the appearance of new substitutive goods or the decrease of the value of time. If we think of a forest, for instance, it is possible to find substitutive products for the wood, but not for other of its functions like its ecological value (for example in the absorption of pollution or its influence on the weather) or its recreational value , that can even increase as time goes by. A similar idea could be applied to fishing grounds, the flora and fauna of the planet or the aquifers, among others.

6.1. Non-biological: the problem is that we are dealing with public goods within the same generation, with no restrictions to its use, and so there is no mechanism acting to balance its destruction. Each agent has incentives to do actions implying the partial destruction of these goods, since they only perceive a small part of the costs and on the contrary they receive all the benefits of their actions. Then, we are talking of resources that should also be public between generations; but they are not precisely because of the consequences of being public within one same generation. The solution to the efficient management of this kind of resources needs to take into account the theories of externalities and public goods. A mechanism has to be found so that the costs due to the depletion of the resource accrue directly on the agent causing them, and they do not dilute in space or time. The existing literature on this matter is very abundant, and so are the proposals to solve the problem[16].

6.2. Biological: to begin the analysis we need to know the resource renewal rate. Each case will show different values, but in general it can be assumed that there exists an optimal amount of the resource (X^*) related to a growth rate als[17] (c^*). If the amount of the resource is above or below that optimum level, the growth rate will also be smaller. This is showed in Figure 2, which represents a fishing ground typical "reproduction curve" (Romero, 1994)

[16] See Pasqual (1991) for a survey and brief summary of different proposals. Other references can be found in Romero (1994) and Magadán y Rivas (1998).
[17] See Romero (1994)

Figure 2



When facing the problem of the optimum management of the resource we can find three possible scenarios:

A) $X = X^*$, that is, the amount of available resource is the optimum and its growth rate (or reproduction rate) is also the optimum, $c=c^*$, as in the case of A in Figure 2. As a conclusion, it follows that to accomplish the sustainability constraint and in consequence that there exists no opportunity costs for the FG, the PG could consume a part of c^*X^* in each period, and this guaranties that at any moment of time there exists an optimum available amount of resource X^*. We are implicitly considering that the PR exclusively belong to FG, while PG keep the right of using the good: they can not destroy the resource (Scenario II or III in Table 1).

B) $X > X^*$. It corresponds to a point like B in Figure 2. The initial amount of the resource is above the optimum ($X_2 > X^*$), and this causes its renewal at an smaller rate ($c_1 < c^*$). As can be seen in the graphic, the effect of an initial amount of the resource superior to the optimum is exactly the same that when the opposite happens, that is, if we start of a deficit situation[18]. When faced to this kind of problem, the question will be which part of the resource can be consumed by PG. There will basically exist two possibilities fulfilling the sustainability requirement:

(B.1) To consume at the growth rate c_1, that is, keeping constant the initial endowment above the optimum of the resource ($X_2 > X^*$).

(B.2) To consume all the excess of initial endowment (X_2 - X^*) and then to consume according to the optimum growth rate c^* in order to keep the level of the resource in X^*.

[18] However, there are different causes. If we think of a fishing-ground, for instance, if the quantity of fish or biomass is above the optimum, its growth rate will be inferior mostly because of problems like the lack of physical space or food. When the initial quantity is below that considered as optimum its growth rate will be smaller due to the impossibility of a faster or in a greater number reproduction.

In the first case there would be no opportunity cost for FG, while in the second one this cost would certainly exist. The solution is to treat the excess of initial endowment (X_2 - X^*) as a non-renewable and non recyclable resource, analyzed in 5.2, and then to carry out the exploitation according to the optimum growth rate c^*, to guaranty the availability of an optimum amount of resource (X^*) at any moment in time.

C) $X < X^*$. This is the most complicated situation and, in fact, the one most often found in real world. Thus, the available amount of a certain natural resource is below the level regarded as optimum, and consequently, its growth rate is also smaller than would be desirable (point C in Figure 1). As a result the analysis in this scenario appears to be the most interesting one with respect to its practical implications. The possibilities for the PG to take action, in a situation like the one described above and ruling out the possibility of consuming at a rate implying a decrease of national wealth -this would be against the requirement of sustainability-, would be the following:

(C.1) To consume at a growth rate $c_1 < c^*$ related to the amount of resource initially available $X_1 < X^*$. The argument is very simple, since the PG have inherited the amount X_1 there is no need for them to renounce to their own consumption in favor of FG.

(C.2) To consume according to a growth rate c_2 inferior to c_1 ($c_2 < c_1$), in a way that at the end of each period there is an amount of the resource superior to the initial endowment. After several periods following this consumption rule the resource endowment would reach the optimum level (X^*), and so there should be a shift to the optimum growth level consumption (c^*).

The first option would be the only one satisfying the sustainability requirement in a strict sense, because the second one would go beyond, in the sense that it permits to increase the initial available amount.

The next step must deal with the identification of the best option from a social point of view, and to do so we need to clarify whether the objective function guiding the analysis only includes the welfare of PG or it also includes that of FG. Table 2 shows the four possible combinations depending on whether the investment is profitable from the point of view of PG (I y III) or not (II y IV), and depending on the consideration of FG and GP (I y II) or only PG (III y IV):

Table 2

	VAN(PG)>0	VAN(PG)<0
VAN(PG, FG) >0	I	II
VAN(PG, FG)<0	III	IV

The situations in I y IV do not raise any conflict, because they imply either that the project is profitable (I) or that it is not (IV) from both points of view. By contrary, in situation II PG would not invest because they do not take into account the benefits for FG; in III the PG would certainly invest because they do not consider the costs caused to FG.

In the following paragraphs we attempt the analysis of the previous three conducts. We assume that each generation lives 2 periods and they overlap, in a way that in period 1 it is PG who live; in period 2 the first FG is born (GF_1), and that will coexist during that period and with GF_2 in period 3, and the same with the following generations. We consider an infinite number of generations, to simplify the calculus of the present value, being *r* the intertemporal discount rate.

Table 3

	PG	PG FG_1	FG_1 FG_2	FG_2 FG_3		FG_{G-1} FG_G	
period	1	2	3	4	...	G+2	...
project C.1	c_1X_1	c_1X_1	c_1X_1	c_1X_1		c_1X_1	
project C.2	c_2X_1	c_2X_1	c^*X^*	c^*X^*		c^*X^*	
project C.2'	c_3X_1	c^*X^*	c^*X^*	c^*X^*		c^*X^*	

Notes:
a) $c_3 < c_2 < c_1$
b) projects C.2 y C.2' are two particular cases of action C.2, depending on how many periods are needed to recover the initial endowment of the resource.

- If the objective function regards solely the welfare of PG, then projects (C.1), (C.2) y (C.2') must be compared according to their NPVs (Net Present Values) calculated until period 2 only, the moment when that generation disappears, that is:

$$NPV(C.1) = c_1X_1\frac{2+r}{1+r}$$

$$NPV(C.2) = c_2X_1\frac{2+r}{1+r}$$

$$NPV(C.2') = c_3X_1 + \frac{c^*X^*}{1+r}$$

It follows that:

NPV(C.1) > NPV(C.2)
NPV(C.2') > NPV(C.2)
NPV(C.1) and NPV(C.2') are not comparable *a priori*.

Thus, it results obvious that project (C.2) is the least profitable, because it implies an inferior level of consumption with no other additional benefit -here, the benefit for FG is not taken into consideration. Between projects (C.1) y (C.2') the resulting sign is not clear, and will depend on each particular case. The conclusion that follows is that the best proceeding is not necessarily the one leading the amount of the resource to the optimum,

as it has been pointed out several times[19]. At every case that will depend on the value of the parameters (c^*, c_2, c_3, X_1, X^* and r).

- But since we are interested in obtaining intergenerational equity following the sustainability principle, the objective function must result from an aggregation of the welfare of both PG and FG, and so the NPVs of the projects will take different values. It must be taken into consideration that in order to obtain the NPV of each project it is necessary to discount both intertemporal and intergenerationally. In the first case, the flows corresponding to each generation must be aggregated, using the intertemporal discount rate (*r*), then obtaining a NPV value for each generation, and to sum up these generational NPVs using the intergenerational discount rate (*R*). The calculus of the profitability of a project typically has been done with the use of and intertemporal discount rate (*r*), this implying that the possible influence on different generations is not taken into account, but rather that the analysis is done as if the effect was on a single generation, or on an individual, with an infinite life. However, in recent years several researchers have pointed out the huge mistake of this procedure, and the need to estimate and apply the intergenerational discount rate *R*[20] so as to guaranty the proper working of the decision process.

The NPV for every of the proposed alternative procedures, and assuming that the number of generations is infinite[21], will be:

$$NPV(C.1) = c_1X_1\frac{1+r}{1+r} + c_1X_1\frac{2+r}{1+r}\frac{1}{R}$$

$$NPV(C.2) = c_2X_1\frac{2+r}{1+r} + c^*X^*\frac{2+r}{1+r}\frac{1}{R}$$

$$NPV(C.2') = c_3X_1 + \frac{c^*X^*}{1+r} + c^*X^*\frac{2+r}{1+r}\frac{1}{R}$$

Comparing the NPV of the three projects we can not reach any true statement. Any of the three can be considered *a priori* better or worse to the others. Again, the result will depend on the concrete values of the parameters related to every resource, and on the discount rates -intertemporal and intergenerational-. In any case, it can be anticipated that

[19] For instance, see Romero (1994). In his analysis the existence of generations is not considered, but it is based in a single individual (or generation) with infinite life, which is equivalent to considering the welfare of PG only, as this is done in the present section. Romero sustains that the most appropriate conduct when the initial endowment of the resource is below the optimum is always to take it to the optimum, always assuming that the investment results profitable.

[20] Kula (1982) was one of the first economists to show the error of discounting only with the intertemporal rate, and pointed out the need of calculating separately the NPV for each generation affected by the project. But the analysis is not completely correct because then he suggests the simple sum of all the generational NPVs, what would be equivalent to assume a R equal to zero. Other researchers pointed out this mistake (Nijkamp and Rouwendal, 1986; Bellinger, 1991) and tried to solve it (Padilla, 1997; Pasqual ,1998). Up to the moment the only known estimation of the intergenerational discount rate, R, is in Iturribarria (1998).

[21] Using that $\sum_{t=1}^{\infty}\frac{a}{(1+r)^t} = \frac{a}{r}$

the sustainability requirement is a necessary but not a sufficient condition to guaranty the maximum welfare.

From the previous analysis important conclusions follow. First of all, the separate study and treatment of every particular case is needed. No general rules for all renewable resources can be derived, but instead the analysis must be undertaken for each of them, or for every group of resources in a similar present situation and similar characteristics too. Then, first of all we should make available a sort of stock list including all natural goods, classified in renewable, non-renewable and environmental. The following step would be the in-depth study of every one of these resources, starting with the determination of its variation rate and its sustainable use level depending on the available stock, and the present situation. In the third place, to carry out the evaluation taking into account the effects on future generations, there is a need to estimate the intertemporal discount rate (r) to be able to sum up the flows affecting the same generation in different periods of time, and the estimation of the intergenerational discount rate (R) to be able to aggregate the flows belonging to different generations. At last, but not least, it arises the need of the design and functioning of a series of institutions *representative* of FG nowadays.

7. Concluding remarks

Throughout this work we have attempted the analysis of the distribution of natural capital among generations, starting from the sustainability requirement, strongly demanded from the environmental economics field, and defined as the necessity of not diminishing the welfare among generations -assuming a constant population. To do so three main categories of resources have been distinguished, namely free, non-renewable and renewable. Each of these types of resources has specific features that justify their separate treatment. Table 4 summarises the main results.

For the case of non-renewable resources it has been proved that the efficient and sustainable allocation among generations demands the assignation of the PR to future generations, keeping for the present ones the right of using these resources in return of the payment of the shadow price of the *in situ* resource corresponding to the PR.

For the case of renewable but non biological goods, their characteristic of free-access permits their destruction by some users paying a null price. The solutions given up to now are based on the theories of externalities and public goods, like pigouvian taxes.

The last case, and also the most interesting one in practical terms, is that of renewable biological resources. This type of resources are featured by what has been denominated *renewal curve*, which represents a relationship between the growth rate of the resource and its existing amount. Three possible situations can be distinguished, and they are that the initial endowment is above, below or is equal to the biological optimum. The consequences in terms of the intergenerational equity are quite different. Unfortunately, the most common case in practice is the inefficiency as the default situation. Thus there exist an amount of the resource below to the desirable level, and as a result its reproduction level is likewise smaller. After proceeding with a more detailed analysis of this case we have been able to prove that the sustainability requirement is a necessary but not sufficient condition for the efficient allocation of resources among generations. Another outstanding result is that, in an scenario like the one described, with an amount of the resource below the optimum, the best option does not

necessarily imply a reduction in the consumption of the resource to lead the endowment to the optimum. The best strategy to follow will depend on each particular case, since in fact we are talking of a investment project that needs to be evaluated.

Summarising, the conclusion for the case of renewable resources is that their efficient allocation will depend on each particular case, being necessary to carry out the evaluation to have at disposal the calculus of the discount rates both intertemporal (r) and intergenerational (R). And the general conclusion is that, to be able to decide the allocation in an efficient way, we must first have a list with all natural existing goods, classified in free, renewable ans non-renewable. Each good must be valued in monetary terms. And in second place, there is the need to design and set in motion a series of institutions acting as representatives of future generations, with the role of guaranty the accomplishment of the established property rights and in charge of the management of their capital in the most profitable way. An appropriate level to undertake this kind of proceedings would be the regional. A general proceeding in this matter at the international level appears as impracticable at the moment. At the national level would still involve important difficulties. However, in the Spanish case for instance, each region possesses certain levels of self-government, and they could have an appropriate size to undertake their own inventory of natural resources. This would not exclude cases when certain goods would demand an agreement at the national level, especially regarding at its valuation. At the same time it must be taken into consideration that we have so far dealt with the distribution of resources on the basis of *quantity*, and this does not exclude the possibility that local strategies obtain outstanding results, what would not happen with strategies developed on the basis of prices due to the economic globalization level reached nowadays. For this reason, no region or nation can argue globality reasons to start developing the proposed measures.

Table 4

TYPE OF GOOD	CHARACTERISTIC ACCORDING TO CONSUMPTION		MANAGEMENT
	INTRAGENERATIONAL	INTERGENERATIONAL	
a) FREE (gravity force)	Public	Public	There is no distributive conflict among generations
b) NON-RENEWABLE			
DURABLE (diamonds)	Private	- Public - Private (there is a partial loss)	There is no conflict among generations, except in the part lost, that must be treated as a non-recyclable good.
NON-DURABLE			
* RECYCLABLE (aluminum)	Private	Local public	The PG can use the resource in exchange of paying FG the corresponding PR, equivalent to the value of the amount consumed minus the scrap value: $PR = \lambda X_d [p_s - \lambda (p_t - Cr)]$ [15]
* NON-RECYCLABLE (oil)	Private	Private	The PG can use the resource in exchange of paying FG the corresponding PR, equivalent to the value of the in situ resource: $PR = p_s \lambda X_d$ [12]
c) RENEWABLE			
BIOLOGICAL (dolphins)	- Private (use value) - Public (ecological value, non-use value,...)	Potentially public or private, depending on the consumption pattern followed	- To determine the reproduction curve of the resource. - To determine if the initial amount of the population is above, below or at the optimum - To evaluate the different strategy projects attending to the welfare of FG and under the sustainability principle
NON-BIOLOGICAL (ozone layer)	- Public - Private (there is a partial destruction)	- Public - Private (there is a partial destruction)	According to the theories on externalities and public goods

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