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ANALYSIS

Temporary credits: A solution to the potential non-permanence of carbon sequestration in forests?

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Abstract

The potential non-permanence of sequestered CO_2 emissions is a crucial issue to tackle in order to safely include forestry activities among eligible activities for the Clean Development Mechanism. Rather than looking at accurate ways of securing permanent reductions, some experts studied the possibility of delivering temporary licenses as a way of circumventing the respective drawbacks of previously proposed approaches (e.g. Ton-Year Accounting). This paper focuses on this concept of temporary (or expiring) credits and tries to assess its financial viability using different scenario assumptions while bearing in mind the need to protect the CDM's environmental integrity. Our main finding is that the concept of expiring credits (EC) provides a convincing answer to the issue of non-permanence both from an environmental perspective and from a strictly financial point of view (as it has the property of efficiently dealing with uncertainties and therefore hedges the risk). However, given the specific nature of forestry activities compared with other types of CDM projects, the EC concept should be complemented with additional rules and modalities.

Keywords: Temporary credits; Forestry activities; Willingness to pay; Net present value

1. Introduction

In order to help Annex I countries (all the countries that were OECD members in 1992, countries with Economies in Transition and Turkey) to achieve their objectives of reducing greenhouse gas (GHG) emissions, the Kyoto Protocol provides for the three so-called flexible mechanisms: the International Emission Trading (IET), the Joint Implementation (JI) and the Clean Development Mechanism (CDM). The latter allows Annex I countries to receive emission credits through financing GHG emission reduction (or sequestration) projects in non-Annex I countries (developing countries that do not face such quantitative constraints on their emission levels).[1]

In 2001, "The Marrakech Agreements" have consecrated forestation and reforestation as eligible activities for the Clean Development Mechanism. It

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[1] For a good introduction to the CDM, see Pembina Institute (2002).

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should be noted that this inclusion is limited as a result of the cap put on Land-Use, Land-Use Change, and Forestry (LULUCF) activities under the CDM. According to the Bonn Agreement (8th paragraph of Section VII), net imports of CDM credits from LULUCF activities during the first commitment period "shall not exceed 1% of a party's reference emissions times five". This would mean a market of about 110 Mt CO_2 equivalent for the 2000–2012 period (Bernoux et al., 2002).

The main reason behind the inclusion of forestry activities under the CDM rests on the ability of these activities to sequester substantial amounts of carbon at relatively low cost. Moreover, this inclusion of carbon sinks could provide a first response to forest management problems[2] as well as to increasing deforestation which both represent a serious threat to climate stability since deforestation and changing land-use are responsible for 22% of global annual emissions (IPCC, 1996).

However, the absence of quantitative commitments in developing countries suggest the adoption of a differentiated approach when defining operation rules for the Kyoto Protocol. This is already the case for emission reduction projects implemented outside the borders of an investing country, as a clear distinction was made between such projects in Annex I countries (Joint Implementation) and in non-Annex I countries (Clean Development Mechanism). This distinction is also justified for the elaboration of rules and modalities needed for the inclusion of forestry activities in the two different project mechanisms planned by Kyoto. Accordingly, there should be specific rules and modalities for including forestry projects under the CDM.

Within that context and given the nature of forestry activities, this paper focuses on an alternative approach to reducing carbon dioxide emissions in the atmosphere. Rather than securing permanent reductions, we look at the possibility of promoting temporary reductions. Our aim is to assess the financial viability as well as the environmental effectiveness of the concept of temporary (or expiring) credits (as proposed by Blanco and Forner, 2000).

1.1. Forestry activities and climate change

The problem of global warming is linked to the accumulation of GHG in the atmosphere. The most abundant is carbon dioxide (CO_2) which accounts for some 80% of total GHG emissions. Understanding the carbon global cycle within the planet is thus a necessary step in trying to solve the problem of global warming. This cycle involves all the carbon stocks contained in the different constitutive spheres of the planet (biosphere, hydrosphere, atmosphere and lithosphere). These stocks varies based on the different flows (CO_2 flows) that are initiated by the "emitting" and "sequestering" agents. The forces that influence CO_2 movements are both of natural and anthropogenic origin.

1.2. Terrestrial sequestration

Some human-induced activities can interfere with the global carbon cycle by engendering CO_2 flows from the atmosphere to other spheres of the earth's ecosystem. These activities allow for the sequestration of CO_2 and help slow down its accumulation in the atmosphere. Afforestation (*the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land*) and reforestation (*the direct human-induced conversion of non-forested land to forested land, …, that did not contain forest on 31 December 1989*[3]) are listed among these activities.

But these two forestry activities have a double role in the carbon cycle as they can turn out to be net emitting sources in case of accidents (fire, pest, etc.) or as a result of intentional acts like deforestation (Ellis, 2001). According to some authors, the warming up of the climate could also contribute to change the forests into net CO_2 emitters (see UK Hadley Centre quoted in Dutschke, 2001).

1.3. Potential non-permanence

From all the arguments that were put forward during the international negotiations against the inclusion of sequestration projects into the CDM, this potential

[2] As improvement management practices can increase the total amount of carbon stored in a forest (Ellis, 2001).

[3] See the Annex of decision 11/CP.7 in FCCC/CP/2001/13/Add.1, p. 58.

reversibility is probably the most critical one (Blanco and Forner, 2000). This problem is commonly referred to as the "permanence" issue (Ellis, 2001).

As mentioned above there are many factors – natural or anthropogenic – that could cause a re-emission into the atmosphere of the carbon that had been previously stored in the trees following the implementation of a forestry project. In addition, no one can assure that the amounts of carbon stored by a forest will indefinitely continue to be sequestered when the project reaches its end. This fact brings up a real challenge which is to scientifically assess the minimum period during which a ton of carbon would need to be sequestered for it to generate a real environmental benefit (see the discussion in Dutschke, 2001 or Moura-Costa and Wilson, 2000).

1.4. Other problematic issues

It is important to underline that there are many other CDM-related problems (i.e. that arise from the fact that CDM host countries do not face GHG targets) to be taken into account before implementing a forestry project. These problems (such as additionality, measurement, supplementarity or leakage effects) are obviously not specific to forestry projects. However, we will show in Section 6 that the intrinsic characteristics of forestry activities call for a reinforcement of modalities relating to the treatment of these other aspects.

2. The concept of expiring credits

Expiring (or temporary) credits (as proposed by Blanco and Forner, 2000, who also credit Chomitz, 2000a for a variant proposal) can be considered as one possible solution to the potential "reversibility" of reductions obtained through the sequestration of carbon in trees. But several other approaches have been proposed in the past to tackle this issue of non-permanence.

A first possibility would consist in using an equivalence factor. This option builds on a premise that once it has been sequestered for a sufficient number of years, a ton of carbon captured in a tree becomes equivalent to a permanent reduction. This reasoning is because a ton of carbon emitted to the atmosphere does not result in a permanent 1-ton increase in the atmosphere. Rather the increase in atmospheric concentration decays with time as some of the carbon mixes into the ocean and the biosphere (Marland et al., 2001).

If we assume, for example, that the equivalence factor is equal to 55 (as suggested by Moura-Costa and Wilson, 2000), 1 ton of carbon sequestered during 55 years may, as a result, be considered as a permanent reduction of a ton of carbon[4] (which implicitly means that 55 tons sequestered during a year are as beneficial for the environment as 1 ton sequestered during 55 years).

This method is known as the "Ton-Year Accounting (TYA)" (Moura-Costa and Wilson, 2000). However the TYA method is quite controversial given the scientific uncertainty concerning the value to be attributed to the equivalence factor. According to different studies, this factor fluctuates between 42 and 150 years, (Marland et al., 2001; Artusio, 2001) and choosing between the different alternatives is thus a policy decision (Chomitz, 2000a; Marland et al., 2001; Cacho et al., 2003). Moreover, attributing a very high value to this factor severely hampers the financial attractiveness of sequestration projects (Ellis, 2001; Cacho et al., 2003).

The "average storage capacity (ASC)" is a second approach (Phillips et al., 2001). It starts off with the same idea of proposing a solution to the potential non-permanence of sequestered CO_2 emissions using a specific accounting method for determining the amounts of credits to be delivered. According to the ASC method credits are issued every year according to the stock increase up to the point where it reaches the expected ASC (e.g. for a forest activity giving rise to a sequestration of 25 tons of carbon annually during 20 years the ASC would be 262.5 tons).

The introduction of liability mechanisms is a third solution. According to this option, the host country would be responsible for any release of carbon which would then have to be made up by an equivalent reduction elsewhere. This unlimited and permanent liability obviously caused general outcry among the developing countries. They consider this principle as a constraint upon their sovereignty and a threat to their food security because their land would no longer be under their own control (Blanco and Forner, 2000; Artusio, 2001).

[4] Note that this assumption is rejected by Meinshausen and Hare (2000).

In sum, none of the above-mentioned approaches have received wide political support so far (Chomitz, 2000b; Blanco and Forner, 2000; Artusio, 2001). There exist yet a few other approaches (minimum duration, buffer credits, etc.), but most of them seem to have failed in gaining support when they were first considered.

This subsisting divergence of views concerning the best methodology to adopt for dealing with the "permanence" issue lead some experts to study the possibility of delivering expiring (or temporary) licenses as a way of circumventing the respective drawbacks of the commonly proposed approaches (Chomitz, 2000a; Blanco and Forner, 2000; Artusio, 2001; Marland et al., 2001; Phillips, 2002; Cacho et al., 2003). Based on that idea of expiring licenses, a proposal was officially presented by the Colombian delegation at the 13th meeting of the Subsidiary Body for Scientific and Technological Advice which took place in Lyon in 2000.[5]

2.1. Colombian expiring credits (EC)

ECs are credits issued every year to a forestry project's promoter according to the increase of carbon sequestered and on a temporary basis (i.e. their validity is limited in time). When the credit falls due (when their validity period is over), the user either has to replace it by another equivalent EC, by a permanent credit or by a supplementary reduction (Blanco and Forner, 2000).

In the event of the carbon being released into the atmosphere before the end of a project (whether by accident or not), it would be the entire responsibility of the project proponent (i.e. the host country—except for joint ventures for which responsibility would be shared between the host country and the investor from the Annex I country) (Blanco and Forner, 2000). The project's duration is a factor to be determined by the project's promoter (provided future rules are flexible enough to do so) whereas the time of use is independent from the project date and is left to the buyer's choice (i.e. EC can be kept for a later use although this partly defeats the initial purpose of purchasing an expiring credit).

[5] Note that Kenneth Chomitz and Gregg Marland presented similar proposals at about the same time.

In short, the key-factors of the system are (Blanco and Forner, 2000):

Duration of the project (D): number of year the project is going to last
Emission date of the EC (t): date on which the EC is certified
Validity period (VP) of the EC: number of years of validity of an EC ($D-\mathrm{t}$)
Date of withdrawal (DW) of the EC: date at which the EC is used
Expiration date (ED) of the EC: date at which the EC is to be replaced (=DW+VP)

2.2. Advantages of ECs

ECs offer many economic as well as environmental advantages. This approach is relevant as it acknowledges the environmental benefits of an even temporary reduction of CO_2 levels through sequestration. There are many arguments in favour of the implementation of ECs (see Chomitz, 2000a; Marland et al., 2001; Artusio, 2001; Lecocq and Chomitz, 2001). They concern:

- the buyer:
  - ECs leave time for technical progress and development of new alternative solutions
  - they make it possible to get the implementation periods of reduction measures to coincide with the end of the capital's economic life (e.g. relevant for power stations, buildings, etc.)
  - they could bring economic benefits provided the costs of emission reductions decrease (or, at least, do not grow as fast as the discount rate) and as long as the sequestration is rather cheap.
- the seller:
  - ECs imply less constraints as far as sovereignty and food security of the host countries are concerned
  - selling them can prove profitable from a strictly economic point of view
  - they allow for the implementation of small short-term project.
- the environment:
  - the atmosphere is protected from a supplementary CO_2 accumulation with each ton that is sequestrated, which contributes to the stabilisa-

tion of atmospheric concentrations and of global warming effects
– temporary reductions might turn out to be permanent.

This expiring credit approach also gives an opportunity to bypass the problem arising from the impossibility to establish a perpetual insurance. By doing so, it brings a solution to the problem of non-permanence and allows for the possible inclusion of forestry projects in the CDM. If properly designed, this type of project could not only generate economic profits but also social and environmental advantages in favour of local communities (Loisel, 2002).

Note also that as far as projects' additionality is concerned, it is easier to evaluate the baseline for a period that is limited by the EC validity period than for an unlimited period (Artusio, 2001).

2.3. Problems linked to ECs

Here, we must clearly distinguish the problems that are really linked to the concept of EC and the more general problems brought up by the opponents to the inclusion of sinks in the CDM. Besides the general modalities needed for implementing any CDM projects, the most critical issue with forestry-based projects remains the potential non-permanence to which the EC approach seems a priori to provide a convincing answer.

However, the possibility of buying EC might be considered as a mere postponement of commitments and a way of escaping from responsibilities. This would be the case if parties were to rent "for life" or were not willing to apply compensatory reductions once the credits expire because they would have erroneously estimated future carbon prices (Artusio, 2001). It could also provide a perverse incentive for parties to try and negotiate less ambitious objectives for future commitment periods (i.e. for the post-2012 period) (Artusio, 2001).

This problem of an excessive dependence on the use of EC is partly addressed by the Marrakesh Accords which stipulates that such "sinks credits" (i.e. removal units—RMU) are not to exceed 1% of the total emission level of the party for its reference year, and this for each year of the commitment period (UNFCCC, 2001).

From a legal point of view, there might also be problems as using an EC can be deemed equivalent to borrowing (as they postpone the commitment), which is explicitly ruled out by the Kyoto Protocol (Dutschke, 2001). The fact that a buyer can use EC whenever he decides could lead to a situation where the buyer uses an EC issued based on a ton sequestered by a forest that does not exist anymore. This would tend to increase the pressure put on the certification body regarding its liability (Dutschke, 2001).

Finally, we also want to point out the possible perverse incentives that are intrinsic to EC logic (as compared to permanent sequestration). Let us think, for example, of the effects that selecting fast growing alien species could have on biodiversity (see Caparros and Jacquemont, 2003) or the negative impacts of unsustainable practices aiming at generating more credits and generating them as quickly as possible (Climate Action Network, 2002).

These aspects are all the more important given that the potential negative impacts (on water resources, quality of soil, etc.) may appear only later on when the project has come to an end and can no longer be subject to monitoring or verification rules.

3. What is the potential value of an EC?[6]

An EC will only have a value insofar as the potential users are willing to buy it. A buyer will be willing to buy an expiring credit as long as its price is smaller than the difference between the current price of a permanent reduction and the present value of the expected price of a permanent reduction in the future. Thus:

$$\mathrm{WTP}_{\mathrm{EC}(D-t)} = \mathrm{Price}_{\mathrm{PR}} - \mathrm{PV}(\text{ Estimated price}_{\mathrm{PR}(t)}) \tag{1}$$

$$= \mathrm{Price}_{\mathrm{PR}} - \mathrm{PV}\Big((\mathrm{Price}_{\mathrm{PR}})^*(1+\mathrm{ERI})^{D-t}\Big) \tag{2}$$

$$= \mathrm{Price}_{\mathrm{PR}} - 1/(1+R)^{D-t} * \Big((\mathrm{Price}_{\mathrm{PR}})^*(1+\mathrm{ERI})^{D-t}\Big) \tag{3}$$

$$= \mathrm{Price}_{\mathrm{PR}}\Big(1-(1+\mathrm{ERI})^{D-t}/(1+R)^{D-t}\Big) \tag{4}$$

[6] This section is adapted from Blanco and Forner (2000).

where PV = present value; WTP = willingness to pay; $D-t$ = period of validity; $Price_{PR}$ = price of a permanent reduction; R = discount rate; ERI = expected rate of increase of the price of a permanent reduction.

It immediately appears that, for a given EC, the WTP increases with its validity period. It is then the interaction between that WTP and the marginal cost of sequestration that would determine the market price of an EC.

However, analysing the Colombian proposal, and more especially comparing it with other previous accounting methods, would prove difficult mainly because EC validity periods (and thus values) differ. In light of those considerations and of the need for a simplified approach to keep transaction costs as low as possible, it seems more appropriate to use methods referring to homogeneous validity periods. One of the last points to settle is thus to agree on a precise validity period.

With respect to that point, there seems to be a tendency to agree on a 5-year validity period. This gave rise to the tCER5 concept (temporary certified emission reductions[7] valid for a period of 5 years) referred to in some analyses (Phillips, 2002; Loisel, 2002). The advantage of this short horizon is that it reduces both transaction costs and uncertainty. As a matter of fact, it is difficult to take decisions based on a parameter value estimated for 25 years (or more). As a result and because of the risk-averse nature of economic agents, the estimated market price could be higher than the one that would prevail under perfect competition market conditions. From formula (4), the value of a tCER5 for a user is thus equal to:

$$WTP =_{tCER5} = Price_{PR} - \frac{(1+ERI)^5}{(1+R)^5} Price_{PR} \qquad (5)$$

4. Description of our scenario analysis

In this section we introduce our scenario of a hypothetical carbon-sequestration project which will serve as a basis for analysing the tCER5 concept.

4.1. General characteristics of the project

Our hypothetical project is a 20 year-reforestation project starting in 2008, that would make it possible for the sequestration of some 4,200,000 (metric) tons of CO_2 on an area of 10,000 ha. As the only possibility to generate tCER5 is to invest in a sequestration project, it is interesting to estimate the global profit such an investment would bring. This will be performed using WTP values for the different tCER5 the project would generate during its lifetime. Then this benefit can be compared with the cost of CO_2-sequestration in order to assess the financial viability of this kind of project.

From formula (5), there are 3 variables (the current price of a permanent reduction, the discount rate and the expected rate of increase of the price of permanent reduction) to be estimated for the WTP value. The cost of sequestration is a fourth variable to be estimated for assessing the project's profitability. In addition, different scenarios have to be formulated according to the different possible rules and modalities of enforcement that can reasonably be envisaged.

4.2. Hypotheses concerning the price of a permanent reduction

There are many surveys dealing with the price of a permanent reduction in 2010 on a Kyoto-type of international market. However, information is scarce regarding prices in the longer run. Weyant (1999), in a special edition of the "The Energy Journal" dealing with the costs of the Kyoto Protocol, has compiled a series of surveys concerning the price of a permanent reduction in 2008 as well as its evolution up to 2050. However, as this study was carried out in 1999, it does not take two important factors into account (i.e. the U.S. withdrawal and the inclusion of sinks in the Kyoto mechanisms). Accordingly, the values mentioned in Weyant (1999) have to be revised downwards if we want our scenario to be consistent with a lower demand resulting from the U.S. retreat and a higher supply arising from the inclusion of sinks.

More recently, Artusio (2001) used the results of six out of the thirteen models analysed in Weyant (1999) to assess the price of a permanent reduction in 2008. He provided a definition of a low, a medium and a high value. On the basis of his results and those mentioned in Marenzi (2001), regarding the effects of the Bonn–Marrakech Agreements on permit prices,

[7] The certified emission reduction (CER) is the CDM unit which corresponds to a credit of 1 ton of CO_{2eq}.

Table 1
The price of a permanent reduction in 2008

Hypothesis for the price of a PR	High value	Average value	Low value
Price of a PR in 2008 (€ 99/t CO_2)	18	10	6

we have built up a price scenario that is more consistent with the current situation (Table 1).

To build up our scenario, we revised the values mentioned in Artusio (2001) downwards[8] and we obtained an average value of € 10 for the price of a permanent reduction in 2008, which is very similar to the estimated value given in Marenzi (2001).[9]

This operation amounts to a 21% reduction (reduced from € 12.7 to € 10) of the permanent reduction when taking recent changes into account. As far as the two extreme values are concerned, we respected the scale and took a value roughly equal to $\$_{95}$ 5 as a lower-end value (which is consistent with the price interval for credits obtained through CDM projects). The upper-end value is comparable to the maximum value adopted in the case of a co-ordination between the countries possessing "hot air" (Eyckmans et al., 2001).

4.3. Hypotheses concerning the evolution of permanent reduction (PR) prices

Estimating the price of a PR in 2008 is already uncertain in many respects which makes it even more difficult to foresee its evolution during the 2009–2028 period. One possibility of taking that uncertainty into account is by making the ERI fluctuate in a range between 0 and the discount rate R (as the WTP for tCER5 becomes zero, when the ERI crosses that threshold). We could even start with an ERI below 0, considering that the technical progress could lower the costs in real terms. This type of analysis based on range of values for ERI will be carried out at the end of Section 5 for an R fixed at relevant values.

To make it easier to study the different possible scenarios, the potential values for ERI will first be limited to three levels (high, medium and low), in parallel with the approach adopted in Section 4.2 (Table 2). To set those values, we also used the multi-model analysis performed in Weyant (1999). Using an aggregation of price forecasts for 2050, we can infer the annual rate of increase for the PR price based upon low, average and high scenarios.

Table 2
Scenarios for the evolution of the PR price

Evolution of the price of a PR	High value	Average value	Low value
Annual ERI for PR price (%)	5.5	3	0.5

The major disadvantage of this approach arises from the fact that it implies a constant annual rate for the whole period, which is unlikely to be the case in reality.

4.4. Hypotheses concerning the discount rate (R)

The discussion surrounding the most adequate discount rate to be used in environmental matters is very extensive and far from being closed (see for instance Newell and Pizer, 2003). Moreover, the different rates put forward embody different parameters (rate of interest, time preference, etc.), which make it even more difficult to undertake comparisons.

However, in our case, this debate is less relevant as we mainly focus on assessing financial attractiveness neither evaluating environmental assets nor undertaking analysis over a period of time which would require us to take intergenerational equity into consideration. The values we used are commonly used values in relevant literature and are based on the opportunity cost of capital (Table 3).

Most analysts consider that the social time preference is more or less equal to 2% (Eyre et al., 1997). This means that the difference (i.e. 8%) between our chosen maximum rate and this very value may be assimilated to the maximum opportunity cost of capital in our analysis.

Table 3
Relevant values of the discount rate

Hypothesis relative to the discount rate	High value	Average value	Low value
Discount rate (%)	10	5	3

[8] We used an average exchange rate Euro/Dollar of 1.11 and a GDP deflator of 1.06 for the 1995–1999 period to convert amount expressed in $\$_{95}$ in amount expressed in € 99.

[9] Actually they came up with the same value but in 2010, which is equal to € 9.42 in 2008 if we assume an inflation rate for CO_2-prices equal to 3%.

Table 4
Relevant values for the cost of sequestrating CO_2

Hypothesis relative to the cost of sequestrating CO_2	High value	Average value	Low value
Cost of sequestrating CO_2 (€$_{99}$/t CO_2)	7	2.5	0.6

4.5. Hypotheses concerning the cost of sequestration (CS) of CO_2

Concerning the CS for CO_2, the main problem is the wide variability of data provided by surveys on the cost of sequestration of different type of project across the world. This variability is reflected in the proceeding hypotheses appearing in studies analysing CO_2-prices (e.g. Eyckmans et al., 2001) where the authors start on the premise that the cost of sequestration is equal to zero (because of the lack of adequate information). This vision is far too simplistic since there are many sources of costs (opportunity cost of changing land use, cost of purchasing or renting a land as well as all the operating costs such as labour, monitoring, maintenance costs, etc.) which do not always appear in calculations (for a discussion on the cost of carbon sequestration, see Sedjo et al., 1994 or Newell and Stavins, 2000). The amounts mentioned in Artusio (2001) take this reality into account so they seem to be appropriate for our analysis (Table 4).[10]

5. Results of the analysis on WTP values

For the time being, there is still some uncertainty about several factors (e.g. the accounting method to be adopted, the project's duration or the reduction objectives after 2012). All these situations will be assessed by means of a comparison to a reference scenario varying one hypothesis at a time.

5.1. The reference scenario

This reference scenario has been build using available information about the relative probability of the conceivable situations. According to some experts (Loisel, 2002 or Phillips, 2002), there is a trend towards a system of temporary credit with a validity of 5 years and towards a yearly assessment (certification and verification).

Table 5 shows the number of tCER5 that will be issued all along the duration of the above-described hypothetical project according to an annual accounting approach and on the basis of a linear sequestration from the first year on (this latter hypothesis will be somewhat qualified in Section 5.4).

If, after 5 years, the sequestered tons are still stored (which is supposed to be the goal of the project manager), not only 21 new tCER5 have to be issued (as a result from the annual increase of sequestered tons) but the tCER5 generated during the very first year must also be re-issued. The reason being that having reached the end of their 5-year validity period those tCER5 can be extended for another 5 years (without any obligation to be sold to the same purchaser) as long as the tons that were sequestered during the first year are still stored in the trees. The same reasoning applies for the tCER5 issued during the second year and that can also be added to the credits issued based on sequestration on year 7 (and so on). Similarly, credits generated based on sequestration in both years 2 and 7 can also be added to the 21 credits to be

Table 5
Number of tCER5 generated by the project according to the reference scenario

Year	Sequestrated tons/year/ha	Number of tCER5
1	21	21
2	21	21
3	21	21
4	21	21
5	21	21
6	21	42
7	21	42
8	21	42
9	21	42
10	21	42
11	21	63
12	21	63
13	21	63
14	21	63
15	21	63
16	21	84
17	21	84
18	21	84
19	21	84
20	21	84

[10] The values mentioned in its study being expressed in \$$_{95}$/ton of carbon, we proceeded to the required modifications.

issued for sequestration in year 12 (i.e. for a total of 63 credits).

To evaluate the global WTP per sequestered ton, we have to proceed in stages. To start, we have to calculate the value of tCER5 based on formula (5). For instance, if we assume that the cost of a permanent reduction is equal to € 10/t CO_2 in 2008, that the CO_2-price is expected to rise at a rate of 3% and that the discount rate is equal to 10%, a tCER5 generated in 2008 (certified in 2008) would then cost € 2.8/t CO_2, based on users WTP. This is an acceptable value as it represents 28% of the price of a permanent reduction.

At this first stage, we must not forget to adjust the PR Price according to both the value for ERI and the year in which the tCER5 is certified in order to account for the fact that the PR price varies over time. For example, if a tCER5 is certified during the third year, you have to start with a PR Price equal to the 2008 PR price multiplied by a factor $(1+\mathrm{ERI}^3)$ and then introduce it to Eq. (5).

In the second stage, this calculated value for a tCER5 issued at a given date is then multiplied by the number of tCER5 that were issued at the same date (e.g. 21 for the first year, as shown in Table 5) and this, for every year of the project's duration (i.e. 20 years in the reference scenario).

The third step consists in performing a discounted sum of the yearly flows identified during the second stage.

Finally, we divide this global present value by the number of sequestered tons (i.e. 420 in the reference scenario) to get the WTP per ton relative to our hypothetical project. This amount is then compared to the cost of sequestration for a ton of CO_2 to assess the financial viability of the project.

Table 6 gives us an idea of the counter-intuitive effects resulting from the accounting method that is used. Although we know from formula (5) that the value of a single tCER5 rises in line with the gap between the two rates (i.e. when discounting weighs more than the ERI), the WTP/sequestrated t CO_2 of our hypothetical project (according to our reference scenario), is higher for an ERI of 3% (€ 3.25/t CO_2) than for a lower ERI of 0.5% (€ 3.17/t CO_2), with a fixed R equal to 10%.

However, the results in Table 6 still match the idea that, for a given ERI, the global WTP/sequestered t CO_2 increases with R. In the other scenarios, we will

Table 6
WTP[a] (€ $_{99}$/t CO_2) for a tCER5 according to the reference scenario

Reference scenario			
Price of a PR in 2008 is assumed equal to 10 €(99)			
R	ERI		
	5,5%	3,0%	0,5%
10,0%	2,94	3,25	3,17
5,0%		1,84	2,87
3,0%			2,13

[a] WTP values are coloured based on a comparison with sequestration costs according to the following code: x standing for WTP for a tCER5, a WTP value is coloured in grey if ERI $\geq R$; in yellow if $x<0.6$; in blue if $0.6<x<2.25$; in green if $2.25<x<7$; in light green if $x>7$.

show that it is not always the case. The reasons for these counter-intuitive values are explained more thoroughly in Appendix A ("Analysis of flows and WTP curves") as the purpose of this section is only to comment and analyse the general effects originating from change in core hypotheses with respect to the reference scenario.

Finally, we note that the discounted flow of benefits is always higher than the minimal sequestration cost (i.e. € 0.6/t CO_2), so that the project would be profitable from a strict financial point of view. The higher the discount rate, the larger the range of values for ERI for which the project is profitable based on a comparison with the average value for the cost of sequestration (i.e. € 2.25/t CO_2). Ideally this range should be as large as possible considering that ERI is the only uncertain value remaining once the price for 2008 is known and the applying discount rate is determined. However, our hypothetical project would never be profitable to undertake if sequestration would cost € 7/t CO_2.

5.2. The post-Kyoto scenario

Up to now, nothing has been decided yet at the international level about future commitments after 2008–2012 but formal discussions must start at least 7 years before the end of the first commitment period (i.e. before 2006) (UNFCCC, 1997). However, it is quite likely that future objectives will be strengthened, in accordance with scientific data that call for a stabilisation of GHG concentration in the atmosphere in the midterm. Indeed, if we are to prevent the accumulation of more greenhouse gas into the atmosphere, we must emit less than natural sinks can absorb quickly (IPCC, 2001). This means that stabilisation is only possible if reduction rates are higher than those specified in the Kyoto Protocol for the period 2008–2012. Not only might this have a great influence on the price of permanent reduction (PR) during the first period considered (through banking for speculative and/or risk-hedging purposes) but it will also have an impact on the evolution of that price in the future.

To assess the impact of heavier constraints on PR price, we use the same value as the one used in Artusio (2001). Due to a lack of information, he assumes that strengthened objectives will result in the PR price increasing by 50% by 2033 (as in this study, the analysed project has a 25-year lifetime starting from 2008). This is equivalent to an additional yearly increase of 1.6%.

It is interesting to note that, contrary to what we might have expected, we cannot uniformly draw conclusions for all of the values, as when $R=10\%$ and ERI = 0.5%, the WPT increases as a result of stronger constraints (see Appendix A for an explanation). The only conclusion we can draw is that, when ERI (here incremented by 1.6%) is very near to R, the WTP is very low. When $R=5\%$ and ERI = 3% (i.e. 4.6% in this scenario), we even reach for the first time a lower WTP level than the minimum threshold of CS = 0.6 €$_{99}$/t CO_2 (Table 7).

5.3. The "5-year accounting" scenario

There is another possible tCER5 accounting method. It corresponds to a tCER5 also valid for 5

Table 7
WTP[a] (€$_{99}$/t CO_2) for a tCER5 according to the "post-Kyoto scenario"

"Post-Kyoto" scenario			
Price of a PR in 2008 is assumed equal to 10 €(99)			
R	ERI		
	5,5%	3,0%	0,5%
10,0%	2,38	3,11	3,25
5,0%		0,47	2,34
3,0%			0,98

Table 8
Number of tCER5 generated according to the "5 years accounting" scenario

Year	Sequestrated tons/year/ha	Number of TCER5
1	21	0
2	21	0
3	21	0
4	21	0
5	21	105
6	21	0
7	21	0
8	21	0
9	21	0
10	21	210
11	21	0
12	21	0
13	21	0
14	21	0
15	21	315
16	21	0
17	21	0
18	21	0
19	21	0
20	21	420

years but only issued every 5 years, in order to make sure the issuance periods match the commitment periods. In this particular case, there would only be one purchase of tCER5 and one price every 5 years. The accounting is shown in Table 8.

Every 5 years, we proceed both to the issuance of the tCER5 generated by the project (based on the verified stock increase during the last 5 years) and to the renewal of the tCER5 whose validity has expired but are still stored by the forest. This corresponds to accounting based on cumulated sequestrated tons at the date of certification. This different method of accounting will of course have an impact on WTP values with respect to the reference scenario (Table 9).

By delaying flows, this accounting method always results in a lower global WTP than in the reference scenario. There is also a first example of a situation where, even with an unchanged ERI, the average R rate gives the same result as the high rate.[11] This results

[11] From the 15th year on, 5% discounting weighs twice as less as 10% discounting which thus compensate for the two times lower value of a TCER5 at a given date (based on formula (5)) with a $R=5\%$ (Price * 0.19) than with a $R=10\%$ (Price * 0.36).

Table 9
WTP[a] (€ 99/t CO_2) for a tCER5 according to the "5 years accounting" scenario

"5 years accounting" scenario			
Price of a PR in 2008 is assumed equal to 10 €(99)			
R	ERI		
	5,5%	3,0%	0,5%
10,0%	2,70	2,83	2,62
5,0%		1,77	2,62
3,0%			2,02

from the fact that the last flows (that are very important as the project generates more tCER5 by the end of its lifetime) are less discounted with the average *R* than with the high *R*.

5.4. The "high forest" scenario

In the reference scenario, we assumed there was a linear sequestration between the first and the last year of the project. This only holds true if the forest is managed in a "coppice" type of way, that means without fining out nor pruning (i.e. technical operations that reduce the mass of wood and thus the sequestered carbon per hectare at a given time). Conversely, with a "high forest" scenario, the sequestration curve would normally be somewhat less linear. However, we would need to know the exact technical management implemented as well as the timing and the intensity of the thinning cuts if we wanted to project sequestration curves for this scenario. In this scenario, we thus assumed that sequestration only starts on the fourth year and linearly increases from then on, as shown in Table 10.

The "high forest" scenario, like the "5-year accounting", postpone the issuance of the first (and thus less heavily discounted) credits. The following table shows that the consequences are symmetric to the "5-year accounting" scenario (i.e. a general decrease of the WTP values) (Table 11).

We must bear in mind that we are comparing two different ways of managing forest plants that do not necessarily yield the same results (Ellis, 2001). It is quite likely that plantations managed using the high forest method will eventually absorb more during the whole project's lifetime (provided it is long enough), even if they do not start absorbing CO_2 before a certain number of years. As we said, sequestration's linearity may also be called into question. There can effectively be periods of declining or even negative sequestration (see the curves in Loisel, 2002 or in Phillips, 2002). Anyway, it is very difficult to forecast how much CO_2 will be sequestered in either modes of management.

Table 10
Number of tCER5 generated according to the "high forest" scenario

Year	Sequestrated tons/year/ha	Number of TCER5
1	0	0
2	0	0
3	0	0
4	24.7	24.7
5	24.7	24.7
6	24.7	24.7
7	24.7	24.7
8	24.7	24.7
9	24.7	49.4
10	24.7	49.4
11	24.7	49.4
12	24.7	49.4
13	24.7	49.4
14	24.7	74.1
15	24.7	74.1
16	24.7	74.1
17	24.7	74.1
18	24.7	74.1
19	24.7	98.8
20	24.7	98.8

5.5. The "30-year horizon" scenario

Following the main arguments in favour of the use of expiring credits (i.e. temporary offset of

Table 11
WTP[a] (€ 99/t CO_2) for a TCER5 according to the "high forest" scenario

"High forest" scenario			
Price of a PR in 2008 is assumed equal to 10 €(99)			
R	ERI		
	5,5%	3,0%	0,5%
10,0%	2,49	2,66	2,49
5,0%		1,61	2,43
3,0%			1,85

permanent emissions), there is no need for the two periods (period of tCER5 issuance and period of increasing sequestration) to correspond with each other. If, after a period of 20 years, the sequestered tons keep being stocked in the trees (instead of being re-emitted into the atmosphere when the trees get cut) the issuance of tCER5 could be extended. Let us assume a term of 30 years. Then the number of tCER5 generated by the project is shown in Table 12.

This extension of time during which the project's promoter receives tCER5 does of course increase the total WTP. Ideally, from a strictly economic point of view, this period should be extended until the marginal WTP increases (i.e. the number of tCER5 multiplied by the discounted value of a tCER5 during the additional year) is equal to the loss of postponing by 1 year the sale of products from cut trees. Table 13 shows the impact of such an extension of time on the WTP/sequestered ton.

For the first time, the project becomes profitable under average conditions (average *R* and ERI, average PR Price and average interval for the cost of sequestration).

If in 2008, the permanent reduction price is as high as €$_{99}$18 /t CO_2 (instead of €$_{99}$10 in the average case) and if the discount rate is as high as 10%, then the project is profitable whatever the cost of sequestration and the ERI (among the specified values).

Table 13
WTP[a] (€$_{99}$/t CO_2) for a tCER5 according to the "30-year horizon" scenario

"30 years horizon" scenario			
Price of a PR in 2008 is assumed equal to 10 €(99)			
R	ERI		
	5,5%	3,0%	0,5%
10,0%	4,31	4,34	3,92
5,0%		3,00	4,17
3,0%			3,37

Finally, let us point out the fact that the counter-intuitive effects described earlier become increasingly important as the lifetime of the project gets longer.

6. Completing the EC approach : key issues to be addressed

As mentioned in Section 1.3, the "permanence" issue is probably the most critical argument put forward against the inclusion of forestry projects activities under the CDM. Other problems (additionality, leakage, etc.) are indeed not specific to this type of project. However, it is important to keep in mind that forestry activities require additional rules insofar as they present very specific aspects that differentiate them from other types of projects (such as energy-

Table 12
Number of TCERs generated by the "30-year horizon" scenario

Year	Sequestrated tons/year/ha	Number of TCER5	Year	Sequestrated tons/year/ha	Number of TCER5
1	21	21	16	21	84
2	21	21	17	21	84
3	21	21	18	21	84
4	21	21	19	21	84
5	21	21	20	21	84
6	21	42	21	0	84
7	21	42	22	0	84
8	21	42	23	0	84
9	21	42	24	0	84
10	21	42	25	0	84
11	21	63	26	0	84
12	21	63	27	0	84
13	21	63	28	0	84
14	21	63	29	0	84
15	21	63	30	0	84

related projects, for instance). These aspects (EU, 2002) are the following:

- forests are living systems, they are subject to natural forces and evolutions, with or without human intervention;
- forests accommodate rich biodiversity and forestry activities may thus have an (positive or negative) influence on this biodiversity, as well as on other important environmental values;
- forestry activities may involve very large areas and have important socio-economic effects on local populations;
- forestry activities in one region may result in activity changes in other regions.

These aspects will likely influence not only the way of treating essential parameters such as the baseline scenario or the leakage effects but also the way of accounting for the uncertainty of measurement.

As far as the baseline scenario is concerned, the challenge will be to find a good balance between the need to promote harmonisation (in order to minimise costs and increase transparency) and the necessity of taking site-specific aspects (for example, the type of soil and biomes, the ecological and climatic variability as well as other socio-economic, ecological and geographical factors) into account as the latter are crucial when it comes to forestry projects (Maréchal, 2002). For example, in the case of abandonment of areas, natural regeneration usually occurs, while in some situations degradation takes place depending on site-specific natural parameters (EU, 2002). In addition, two important factors should be taken into account when estimating the climate benefit of a given forestry project (i.e. measured in terms of reduced tons of CO_2 equivalent): the net equilibrium between carbon, methane and nitrous oxide on the one hand (as other GHG emissions can substantially reduce the benefits of a forestry project according to Ellis, 2001) and the organic carbon contained in the soil on the other hand (Jackson, 2002).

Another crucial aspect to closely consider when dealing with forestry projects is the issue of leakage effects and especially those effects that take place far away from the project's site (e.g. relocation of lumberjacks to other forests, moves in demand for forestry products and transportation of these same products) as they are harder to monitor. A case of 100% leakage could even take place, which is quite unlikely to happen with other types of projects. Therefore, it is advisable to reinforce the existing modalities in order to ensure that forestry projects actually result in global net reductions. This means increasing monitoring provisions to adequately address leakage (e.g. accounting for leakage occurring outside of the project's boundaries) and decreasing the claimed credits according to estimated leakage. Another way could be to strengthen a project's capacity to limit leakage by, for example, incorporating in the project design socio-economic benefits for local people which would provide them an incentive to maintain the project and its greenhouse gas benefits (CIFOR, 2000).

Another measure that could drastically reduce leakage effects would consist in excluding the types of plantations that are more prone to generate this type of phenomenon, such as industrial monoculture plantations (Climate Action Network, 2002).

In addition to this aforementioned uncertainty on two major CDM aspects (i.e. baseline and leakage), forestry projects are also uncertain with regards to emission measurement. In fact, for obvious reasons of cost and feasibility, emissions are never really measured. They are only estimated based on activity data and using emission factors. The problem is that the data and emission factors are not as accurate for forestry activities as they are, for example, for combustion. It is obviously easier to estimate constant, precise and well-defined emission sources than the more vague, fluctuating and diffuse sources such as carbon sinks (Climate Action Network, 2002). Adjusting (or discounting) the number of credits delivered to reflect uncertainty (using IPCC values by default when uncertainty can not be accurately quantified) could be an appropriate way of taking this issue into account as it ensures that each of the credits issued results provides an identical climate benefit.

The possibility of generating substantial sustainable development benefits through forestry projects is also a crucial aspect to be taken into when analysing the potential inclusion of this kind of projects under the CDM. According to the context, sink projects can indeed entail many environmental and socio-economic advantages, in addition to carbon sequestration, such as, for example (Loisel, 2002):

- Protection of water resources;
- Fight against erosion;
- Management of river basins (to avoid floods);
- Diversification of economic activities and income;
- Perpetuation of the wood production by supplying new raw material;
- Wood supply as a way of securing energy supply
- Protection of biological diversity (intra- and inter-specific fauna and flora);
- Fight against illicit culture;
- Improvement of local climate;
- Development of tourism's attractiveness (nicer views);
- Fight against vegetal and animal pest, etc.

But these impacts can easily be reversed if projects are not conceived or implemented appropriately. To this end the IPCC has identified a set of principles to be followed when elaborating a project involving LULUCF activities (IPCC, 2000). Within that context, it is interesting to note that issues relating to the contribution of forestry activities to sustainable development in host countries are connected to the modalities required to account for other key parameters (such as additionality, leakage, etc.). Synergies do exist as suggested by the case of industrial monoculture plantations. In addition to being more prone to generate leakage effects, industrial monoculture plantations are both more vulnerable to pest and to climatic perturbations (Phillips et al., 2001) and more likely to raise socio-economic problems.[12] Thus, providing an adequate filter against non-additional projects, as well as strict modalities concerning the accounting of leakage effects might contribute to avoiding projects that have a negative impact on sustainable development in host countries.

Among the modalities that could have a positive impact on a project's contribution to sustainable development as well as on other parameters, is the extension of the credits issuance period. This would enhance the profitability of planting trees that sequester more carbon but at a slower rate and which give longer lasting products (other products than merely paper) once they reach maturity.

7. Conclusions

At first sight, the concept of expiring credits, and more specifically its modification whereby credits are valid for 5 years (i.e. tCER5), seem to provide an efficient and realistic solution to the potential non-permanence of carbon sequestration. This, both from an environmental perspective (provided it is complemented by a responsibility mechanism for potential re-emissions and by frequent verification) as well as from a strictly financial point of view as our analysis of curves carried in Appendix A shows they have the property of efficiently dealing with uncertainties relating to key parameters' value (i.e. the ERI and the cost of sequestration) and therefore hedges the risk.

Moreover, tCER5 have the advantage of being consistent with the Bonn Agreement that stipulates that the re-emission to the atmosphere of sequestered CO_2 through LULUCF activities has to be "taken into account" and "at an appropriate time" (Ellis, 2001). tCER5 can also be allocated based on "real and measurable" benefits (Ellis, 2001). The renewal of credits even after the sequestration period may result in encouraging the promoters of some projects to sequester CO_2 over longer periods.

However, the rules must be clear and strict in order to avoid undesirable effects that may result from badly conceived or implemented projects (such as projects that use species that are not suitable for the soil and climatic conditions of the project's site). These projects would not only threaten environmental integrity but also reduce the financial viability of forestry projects. Therefore, it is imperative that efficient monitoring and certification mechanisms be set up. Serious eligibility criteria will also have to be defined and applied to forestry projects. To that respect, one must bear in mind that the EC logic tends to favour some type projects (i.e. fast-growing monoculture plantations) which should clearly be rejected regarding their potential environmental and socio-economic problems (as shown in previous sections). Nevertheless, there should be no differences in the way of allocating credits to approved projects.

From the scientific point of view, uncertainties linked to carbon sinks should make us very cautious.

[12] As mono-culture plantations often use fertile lands unlike more diversified plantations which can take place on abandoned lands.

Many factors limit the sequestration's ability of forests. It will thus be very difficult to give an exact estimation of the total sequestered tons for a given project. Taking this uncertainty into account and, if necessary, readjusting the number of credit allocated may be part of the solution.

Finally, it is important to remember that the concept of expiring credits is certainly not the solution to the problem of global warming. However, as the necessary changes cannot occur in one day, this method could prove beneficial, as least temporarily.

Appendix A. Analysis of cash flows and WTP curves

A.1. Cash-flows

The analysis of the results often seemed to be contradictory with intuitive reasoning. In this section, we will try to shed light on the reasons behind these results (see also footnote 9 for a part of the explanation). The following table shows when and how a lower TCER5 value to start is offset and eventually gives rise to a larger global WTP/sequestered ton.

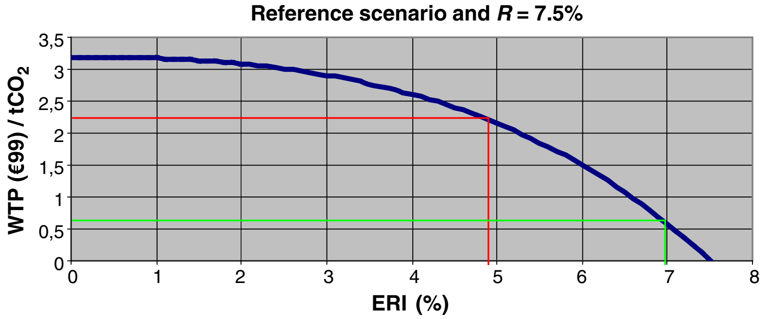
Comparing the first two cases allows us to see why the change in WTP values that we expected to take place as a result of the increased rate *R* (and thus of the TCER5's value) is not verified. In the case of an ERI with a fixed value (here equal to zero), the larger WTP/sequestered ton is obtained for the lower *R* (7.5%) and not with the higher one (8.6%). The smaller discounting of flows with an $R = 7.5\%$ compensates for the lower initial value for a given TCER5 (this compensating effects appears as from the 11th year).

In turn, comparing the last two columns illustrates the same counter-intuitive effect but for changes in ERI values. With a fixed *R* (here equal to 8.6%), the higher ERI (2.2%) gives rise to a larger WTP/sequestered ton than the smaller one (0%). The fastest price increase with the higher ERI compensates for the lower value for a tCER5.

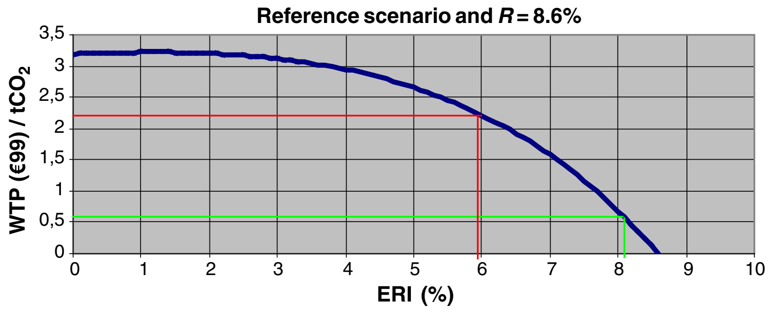
Table A1
Annual flows of revenues generated by the hypothetical project[1]

Price of a PR in 2008 is 10€ $_{99}$/t CO_2			
Values for *R* and ERI	R=7.5%-ERI=0%	R=8.6%-ERI=0%	R=8.6%-ERI=2.2%
Value of a TCER in 2008	3,034413676	3,380108465	2,666828191
Cash flow 1	59,27691833	65,3612134	52,70300795
Cash flow 2	55,14131938	60,18527938	49,59712166
Cash flow 3	51,29425058	55,41922595	46,67427103
Cash flow 4	47,71558194	51,03059479	43,92366942
Cash flow 5	44,38658785	46,98949797	41,33516589
Cash flow 6	82,57969833	86,53682867	77,79841535
Cash flow 7	76,81832402	79,6840043	73,21361003
Cash flow 8	71,45890607	73,37385295	68,89899581
Cash flow 9	66,47340099	67,5634005	64,83864983
Cash flow 10	61,83572186	62,21307597	61,01758759
Cash flow 11	86,28240259	85,92966294	86,13256149
Cash flow 12	80,26270008	79,12491984	81,05660943
Cash flow 13	74,66297682	72,85904221	76,27979267
Cash flow 14	69,45393193	67,08935747	71,7844826
Cash flow 15	64,60830877	61,77657225	67,55408952
Cash flow 16	80,13433646	75,84600645	84,76400183
Cash flow 17	74,5435688	69,83978494	79,76870154
Cash flow 18	69,3428547	64,30919424	75,06778359
Cash flow 19	64,50498111	59,21656928	70,64389947
Cash flow 20	60,00463359	54,5272277	66,48072307
Total WTP	1340,781404	1338,875311	1339,53314
WTP/sequestered ton	3,192336677	3,18779836	3,189364619

[1] This table uses figures from the reference scenario.



Graph 1. WTP curve for the reference scenario and $R = 7.5\%$.



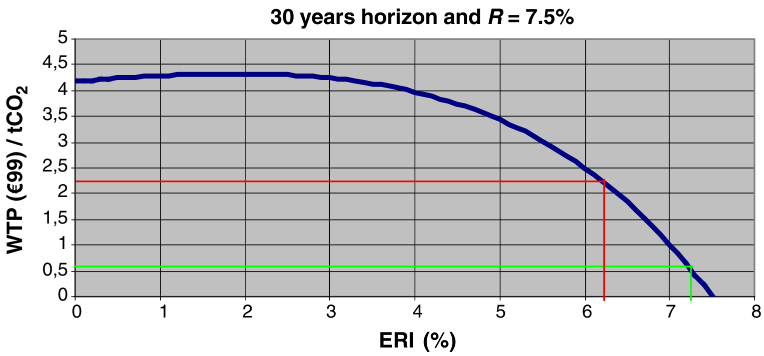
Graph 2. WTP curve for the reference scenario and $R = 8.6\%$.

However, as it is shown on Graph 2, this compensating effect is only sufficient for low ERI.

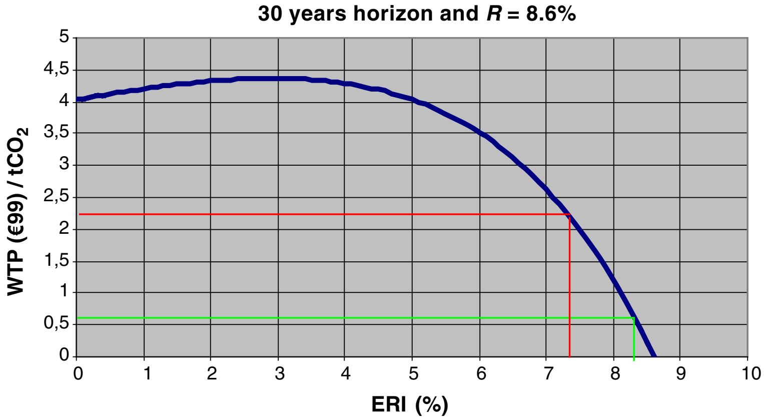
Both of these compensating effects become more important the longer the time period considered. They are also a result of the way tCER5 are generated and accounted for as the closer we get to a project's end the more credits are delivered.

A.2. WTP curves

Looking at WTP curves is another way of analysing how WTP/sequestered ton varies. These curves show how WTP/sequestered ton change in response to changes in ERI assuming a fixed R and a given scenario. ERI varies from zero to the same



Graph 3. WTP curve for the reference scenario and $R = 8.6\%$.



Graph 4. WTP curve for the reference scenario and $R = 8.6\%$.

value of the fixed R (as to this latter value corresponds a WTP value of zero). Figures are based on a price for a PR equal to 10 €$_{99}$/t CO_2.

This analysis of WTP curves is performed for two different scenarios (i.e., "reference" and "30 years horizon"). The purpose of the curves is to allow for a visualisation of how compensating effects occur whereas the choice of scenario is used to illustrate the importance of the period of time considered on those effects.

The first graph (Graph 1) shows that, for low ERI, the WTP is quite stable[13] and then decline slowly without experiencing a drastic drop towards the end. It is important to note that as soon as the ERI differ shortly from the fixed R value, the project becomes profitable based on the low value for sequestration costs (as shown by the green light). The profitability range is still large when WTP values are compared with the average value for sequestration costs (as shown by the red line).

This means that, even though the WTP for a given tCER5 depends on the gap between R and ERI, having projects of relatively long duration (and thus compensating effect playing an active role) allows for the hedging of expected benefits for a wide range of ERI. This definitely constitutes an efficient way of dealing with the uncertainly of this variable. However, it must be balanced with the fact that a larger project's duration also increases uncertainty about many other parameters (as, for instance, the additional increase of price due to a strengthening of the commitments).

Conclusions are symmetric for the case referring to a $R = 8.6\%$ as shown on Graph 2. We just see that the profitability range of ERI values has increased.

The next two graphs (Graphs 3 and 4) show the importance of the time period considered for WTP curves. The "stability" range is wider and the "bell" is more easily distinguishable when the time horizon is extended for 10 years. The gap between the two rates (i.e., R and ERI) needed for a project to be profitable based on minimal sequestration cost is even smaller than for the reference time horizon.

In parallel, the range of ERI for which the generated WTP/sequestered ton value exceeds the average sequestration cost has increased.

[13] Actually, it is more like a bell-shaped curve with a maximum for ERI = 0.1 but changes are rather small.

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