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What are the social benefits of carbon sequestration?

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Abstract

The costs of reducing carbon dioxide (CO_2) emissions or their sequestration have received a great deal of attention. On the other hand, the benefits of the reduction or sequestration have been limited to avoided costs, which in general do not reflect the social benefits. Knowing the benefits to the whole society would help to make rational economic decisions on the amount of resources devoted to carbon sequestration or emission reductions. This article presents the methods based on increasing the amount of carbon stored in the system but it reflects the social value of the society instead of the cost of sequestering carbon.

Keywords:
Social cost of carbon, Non-market valuation, Forest attributes.

1. Introduction

The accumulation of carbon dioxide and other greenhouse gases in the atmosphere is the major reason for global climate change. At current emission rates the accumulation of greenhouse gases in the upper atmosphere is expected to lift average global surface temperature by approximately 0.3-2.5º in the next 50 years and 1.4-5.8º in the next century (Watson *et al.*, 1998; Houghton, 1996). Although economic and ecological consequences of global warming are a subject of debate, numerous scientists believe that negative impacts will likely outweigh benefits (Bruce *et al.*, 1996).

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The participants countries in the third meeting of the FCCC in 1997 in Kyoto, Japan, agreed, through what would later become known as the Kyoto protocol, to reduce greenhouse gas emissions to 5% or more below 1990 levels by 2012. The Kyoto Protocol provides for three flexible market mechanisms to reduce greenhouse gasses. These are emissions trading, joint implementation, and the clean development mechanism. Under the clean development mechanism it may be possible for a country that emits carbon in excess of Kyoto limits to purchase carbon offsets from a country or region that manages carbon sinks. A carbon sink is a natural mechanism that absorbs CO_2 form the atmosphere.

Forests are the most obvious carbon sinks, and one straightforward method for increasing carbon storage is through forestation. Trees absorb (sequester) CO_2 and store it in the wood. Increasing the amount of forests through reforestation and forestation is an obvious alternative to slow or offset the increase in atmospheric CO_2 (Schroeder, 1991).

As trees grow they sequester carbon, but once carbon has been sequestered, no further benefits are forthcoming (Van Kooten *et al.*, 1995). Afforestation on lands capable of supporting trees such as some grassland, pasture lands and land degraded or abandoned following other land uses such as grazing or cropping would significantly expand forest resources and increase the level of terrestrial carbon storage (Sampson *et al.*, 1993). The storage of carbon and it liberation for the forestal ecosystems are considered in the article 3.3. of the Kyoto Protocol.

This storage function of trees is of potential value to society in a number of ways. However without intervention by the government, the market will not provide an optimal level of forestation for carbon storage. This is because the benefits of carbon storage by trees accrue to wider society rather than the forest owner. For this reason is important to estimate the monetary value of carbon sequestration by forests.

With the increasing social awareness of the potential negative consequences of global warming and the link between CO_2 emissions and global warming, the number of studies dealing with the estimation of those negative consequences and their avoidance has exploded. There are different ways to classify those estimations. One is by looking at whether they estimate the cost of decreasing the stock of CO_2 in the atmosphere (cost estimations) or the benefit of such a reduction (benefit estimations). Most of the valuation studies belong to the first group, and can be further divided into two sets: those that look at the cost of reducing emissions and those that estimate the cost of sequestering CO_2. Both sets of studies will be reviewed in the next section.

The group of benefit estimations has received less attention in the empirical literature. They tend to focus on the damages caused by a given raise of temperature. Most of them look at the value of agricultural production loss, or the cost of carbon sequestration in forest. Therefore they take the approach of accounting for effects which values can be observed in existing markets. Although in the theoretical literature it is often mentioned that non-market values may account for a large share of the total social value (Atkinson *et al.*, 2012), the empirical valuation literature related to CO_2 is very limited. In the few instances that we are aware of, they value a bundle of goods, one of the components being carbon sequestration, but without obtaining a specific value for it (Pearce *et al.*, 2004). This paper introduces an attempt to obtain a specific CO_2 sequestration value using non-market based valuation methods.

The present article is centered in the estimation of the social value associated by storing atmospheric carbon dioxide in form of tree biomass, by means of forestation. The relative cost of storing carbon through forestation remains uncertain.

A considerable volume of studies estimates the economic value associated with the carbon storage by forests. Most of them estimated the value as the cost of sequestered the carbon. Therefore, this study participates in the methods based on increasing the amount of carbon stored in the system but it reflects the social value of the society instead of the cost of sequestering carbon.

2. Economic valuation of carbon sequestration

Increased concern by policy makers with the threat of global climate change has brought with it considerable attention to the possibility of encouraging the growth of forests as a means of sequestering carbon dioxide (Bruce et *al.*, 1996).This high level of interest can partly be explained by assertions that growing trees to sequester carbon is a relative inexpensive means of combating climate change (Sedjo and Solomon, 1989; Dudek and LeBlanc, 1990 or NAS, 1992).

The estimation of the economic value of the carbon stored by trees has been the object of an important number of studies (see for example Kulshreshtha *et al.,* 2000 or Richards and Stokes, 2003). The economic value of any resource-environment system lies in the contribution of its ecosystem services and functions to human well-being. Consequently, the economic value of the change in ecosystem service flow can be derived by measurement of the effect on changes in human welfare. To assess the welfare contribution of ecosystem services economists use environmental valuation methodologies (Freeman 2003).

However, no single valuation method can cover the value of carbon sequestration services to society and human welfare. Estimates of the social value of carbon are sensitive to the underlying methodology and assumptions adopted. Each methodology depends on the context of the study, availability of data, theoretical considerations, as well as uncertainty concerning climate change impacts. There is no internationally agreed methodology for estimating the social value of carbon (Meenakshi *et al.,* 2012; Valatin, 2011). For example the different definitions for a "ton of carbon", the land opportunity cost, the initial cost of forestry practices, the maintenance costs of forestry practices, the choice of discount rates, or the administrative costs (Richard and Stokes, 2003).

Several methods of valuation are available to valuing carbon from a societal perspective. Due to different methodologies, models and underlying assumptions used estimates of the social value of carbon are subject to wide variation (Valatin, 2011).One of the principals is the marginal abatement cost (MAC) of reducing emissions or sequestering carbon. Marginal abatement costs (MAC) are the costs of eliminating an additional unit of carbon emissions and a MAC curve can be constructed by plotting CO_2 prices against a corresponding reduction amount for a specific time and region (Ellerman and Decaux, 1998). It provides estimates of the costs of supply of carbon sequestration.

The first studies about the cost of carbon sequestration included only the cost of the tree plantation (Sedjo and Solomon, 1989; Moulton and Richards, 1990) and the disposable wood (Nordhaus, 1991). Most recent studies are more sophisticated, including the maintenance costs of the forestry project (Dixon *et al.*, 1994), the secondary environmental cost and benefits of the carbon sequestration projects (Plantinga and Wu, 2003) or the administrative costs (Richards *et al.*, 1993). However, all estimates are subject to considerable uncertainty. Markets interactions in carbon sequestration program analysis require considerable more attention. Richards and Stokes (2003) suggested that the secondary benefits may be significant, making carbon sequestration a “non-regrets” mitigation option.

There are a vastly different estimates of the costs of sequestration in forests even among studies that have focused on similar regions. As suggested by Richards and Stokes (2003) there is tremendous potential to capture significant quantities of carbon for less than 50 dollars per metric ton and it seems that carbon sequestration in developing countries may be more cost-effective than in industrialized countries

3. Non-market valuation methods

One characteristic of the values of is that they do not take into account the preferences of the society due to a change in the quantity of CO_2. These studies are based on the economic cost that the society should support if some actions for reducing or fixing the CO_2 in the atmosphere are carrying out. However, and for different reasons, the society could or not be willing to pay the cost for achieving some reduction of the CO_2 emissions. The benefit could be similar to the cost, but it, also, could be too inferior o superior. For example, in the case that some reduction of the CO_2 emissions does not affect the social perception positive o negatively, the economic valuation of the perception of the impact would be null, although the cost of the reduction could be too high. Moreover, this approximation does not allow that the people affected could choose their preferred combination of environmental attributes and private goods. At least, most of the application does not take into account that a land conversion to forest would have secondary environmental benefits and cost, beyond the carbon sequestration.

Over the last several decades economists have developed and refined a battery of methods for estimating the non-market values of goods and services, such as those associated with forest. These non-market valuation methods can be categorized as revealed and stated preference methods depending on whether they are based on existing markets or constructed hypothetical markets (Mitchell and Carson, 1989). Revealed preference use observations on how decision makers actually trade off market goods and amenities. The two main methods are the hedonic pricing and the travel cost. The hedonic pricing approach (Rosen, 1974) involves the observation of market prices of goods, and estimates the contribution of each attribute to the price, where one of the attributes is the externality or non-market good of interest. This is done through regression statistical analysis. Another market-based method is the travel cost (Hotelling, 1949). Here, a demand curve relating number of visits to a site and the cost of each visit is estimated, and the consumer surplus derived. Among the stated preferences methods, the contingent valuation method (CVM) is most widely used. Other stated preferences methods, notably choice modelling (CM), are increasing in popularity amongst environmental economists (Bennett and Blamey, 2001). Both use surveys involving a questionnaire that proposes the provision of one or several goods and services in exchange for a cost, for a monetary contribution from the surveyed individual. The stated preferences methods are techniques capable of placing a value on commodities that have a large non-use component of value, and when the environmental improvements to be valued are outside of the range of available data.

3.1 Revealed preference methods

The use of these methods for valuing the carbon is limited. We only have Knowledge of two studies. The first study is an application of Stavins (1999) where he employed an econometric model to derive the costs of carbon sequestration. The method by which the costs of carbon sequestration could be estimated was based on the evidence from landowners' behavior when confronted with the opportunity costs of alternative land uses. The model combines a subsidy on the flow of newly forested land with a tax on the flow of new deforestation. The subsidy was treat as an increment to forest revenues in the forestation part of the model and the tax payment as an increment to conversion or production costs in the deforestation part of the model. The sample used was of 36 countries in U.S. The results obtained were that the marginal costs of carbon sequestration increase gradually, until these costs are about $66 per ton and beyond this point, marginal costs depart more rapidly from a linear trend as higher quality agricultural lands are converted to forested use.

The other application is form Pendleton and Mendelsohn (2000). This study links global circulation models, ecological models of fish catch, and economic models to estimate the impact of a doubling of $C0_2$ on freshwater sportfishing in the north-eastern United States. The economic valuation models used were hedonic travel cost and random utility models. The results were that a doubling of atmospheric carbon dioxide is predicted to generate a $4.6 million loss and $20.5 million net benefit for the Northeast, depending on the climate scenario.

3.2 Stated Preference methods

Stated preference methods use survey questionnaires to create hypothetical markets where individuals express their preferences through their choices. These methods are usually classified in two groups: the contingent valuation methods (CVM), and the attribute-based valuation methods (ABVM), also known as choice modeling methods (Hanley *et al.*, 2001). Both on them represent two different ways of dealing with forest ecosystems valuation. CVM focus attention on the holistic nature of forests, whereas ABVM pay attention to forest attributes which are relevant for policy or management purposes.

In recent years CVM has become a routine tool for academics and policy-makers and has been extensively applied to the valuation of a wide range of environmental goods and services (Mitchell and Carson, 1989; Adamowicz, 2004). The technique has been applied in forest related research to value such things as reducing fire risk in old growth forests (Loomis and Gonzalez-Caban, 1998), recreational benefits (Scarpa *et al.* 2000; Flatley *et al.*, 1996), or wildlife habitat (Loomis, *et al.,* 2000; Breffle *et al.*, 1998).

In ABVM, a set of alternatives (choice set) defined by attributes with different levels (varying across the sample) is presented to individuals. Further, they express their preferences for the alternatives making choices. The kind of choice tasks they have to perform depends on the variant or elicitation method used. Two very common stated preference methods are choice experiments (CE), and contingent ranking (CR). These methods are able to provide more information than CVM, but at the expense of a more demanding statistical treatment and a heavier cognitive burden for the respondents, which could cause unreliable or untrue responses.

Smith *et al.* (1997) used a contingent valuation survey to elicit the compensation required by farmers to switch from slash-and-burn to forest preservation and agroforestry. An indirect willingness-to-pay format was used to elicit the compensation required by farmers to change land use. The compensation should reflect the opportunity costs of forest preservation (or of agroforestry) and is calculated as the difference between the total economic value of forests (or agroforestry) appropriated by farmers and the economic value of the best alternative use of forested land (slash-and-burn agriculture).

According to the results Smith *et al.* (1997) concluded that farmers positively valued the environmental services of forests, implying that slash-and-burn occurs because farmers cannot capture global benefits of forest preservation. The average compensation requested by Peruvian farmers to preserve a hectare of forest in their own land is $246 per year while the mean WTA to convert one hectare to agro-forestry systems is $153. The study was carried in the Peruvian Amazon. Although this study value the change on the welfare, this change only includes the change on farmers welfare and does not take into account the benefits of the people who could be affected by the conservation of the forest. Moreover, although one of the significant global externalities of slash-and-burn agriculture includes the emission of carbon, the environmental benefits from forest preservation could include other environmental benefits like biodiversity, wildlife habitats and recreational services.

Shrestha and Alavalapati (2004) estimated the public demand for some environmental benefits of silvopasture in south-central Florida's Lake Okeechobee using the choice experiment approach. One of the environmental attributes of silvopasture analyzed was the improving air quality due to the carbon sequestration. The implicit prices for moderate and high carbon sequestration levels were $58,05 and $62,72. However, the differences in the WTP values for two levels of improvements in the carbon sequestration were not significant. Although this study allows knowing the willingness to pay of southern Florida population for a change in the absorption of CO_2 from the atmosphere due to silvopasture, it is not possible to know the WTP for a tone of CO_2 absorbed.
Tsang and Burge (2011) used four stated choice studies in the water sector in order in order to apply the resulting values for climate change policy. The study found that households were willing to pay £1.45 to £2.97 per year on their water bill in exchange for climate change related improvement. This premium translates to a willingness to pay of £135- £333 per ton of CO_2 with a potential saving of 0.01 ton of CO_2 per household per year.

In Spain, Mogas and Riera (2005) used the choice in order to estimate the mean of the maximum willingness to pay (WTP) of a given population for changes in their welfare due to a variation in the quantity or quality of some attributes that forests provide. The attributes chosen for the analysis were some recreational activities – such as picnicking, picking mushrooms, and driving motor vehicles on forest ways – CO_2 sequestration and erosion prevention. The study found that an individual mean WTP per person per year of

0,000006990 Euros for the absorption from the atmosphere of a tone of CO_2 and 0,0000256 Euros for a tone of carbon stored on the forests.[2] This value is interpreted as an indicator of the WTP of a representative inhabitant of Catalonia over 18 years old. The population of adult inhabitants in Catalonia in 1999, was 5,3 million of people. The mean WTP was multiplied by the adult population of Catalonia to obtain a measure of the total economic benefits arising from a ton of carbon sequester. The aggregate estimate was 37 Euros for a tonne of $C0_2$.

4. Conclusions

Placing a value on carbon is important in ensuring that effective incentives are put in place to tackle climate change. Forest ecosystems generate a wide variety of goods and services not only for the forest owners but also for society at large. They provide a number of public goods, like carbon sequestration.

As the paper has shown, a variety of approaches to valuing carbon exists. The current valuation of carbon focuses on cost measures, notably the marginal social cost of carbon, which measures the damage imposed by each unit of carbon emitted; and the marginal abatement cost, which reflects the cost of reducing emissions

This article presents a summary of methods for estimating the non-market values of goods and services, such as those associated with forest. These methods allow to estimate how much people are willing to pay, a measure of the value they place on carbon emissions reduction, instead how much people should pay or have to pay.

The willingness to pay method reflects people's subjective welfare, so the method is useful for putting a value on public goods. Their estimation could constitute a significant source of information for further forest policy design and the development of financial instruments.

[2] This estimation was based in the total of CO_2 emissions added to the atmosphere in Catalonia in 1995, equivalent to 6.8 tonnes per person per year (Departament de Medi Ambient de la Generalitat de Catalunya, 1996) and supposing a lineal relation between the annual reduction of CO_2 and the willingness to pay for this reduction.

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