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Policy design for forest carbon sequestration: A review of the literature

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ABSTRACT

Forest carbon enhancement provides a low-cost opportunity in climate policy, but needs efficient policy design to be implemented. This paper reviews studies in economics on efficient design of policies for forest carbon sequestration and compares their findings against design systems in practice. Specific design problems are associated with the heterogeneity of landowners, uncertainty, additionality, and permanence in carbon projects. Different types of discounting of the value of the forest carbon sink compared with emissions abatement are suggested in the literature for management of most design problems, together with optimal contract design and emissions baselines for managing additionality and permanence in carbon sequestration. Design systems in practice, where forest carbon corresponds to 0.5% of all carbon volume subject to a pricing mechanism, mainly rely on additionality tests by approved standards on a project-by-project basis, and on buffer credits for management of permanence. Further development of forest carbon sinks as offsets in voluntary and compliance markets can be facilitated by applying tools for contract design and offset baseline management recommended in the literature.

1. Introduction

The damaging impacts of anthropogenic emissions of greenhouse gases (GHG) have been demonstrated in a number of studies (e.g., IPCC, 2014). Recognition of the need to stabilize the carbon content in the atmosphere has been manifested in a number of international and national agreements and policies, such as the Kyoto Protocol, the Paris Agreement, and the EU climate policy. The main focus of these agreements and policies is on reducing GHG emissions, but the carbon content in the atmosphere can also be offset by carbon sink enhancement. Carbon sequestration occurs in above-ground growing biomass and in below-ground soil from e.g., soil biomass and decomposition (e.g., IPPC, 2014). These two forest carbon pools are linked, as felling of trees releases carbon to the soil and this is incorporated in successional biomass production. Global carbon absorption in these two forest carbon pools in the period 2000–2007 amounted on average to 4.1 Pg C/year (Pan et al., 2011). This corresponds to approximately 30% of the emissions from fossil fuels in 2010 (IPCC, 2014). This absorption is counteracted by the release of carbon in the soil by deforestation. The global release from forest conversion amounts to approximately 2.8 Pg C/year (Pan et al., 2011).

Thus, the potential reduction in release of carbon from avoided deforestation and increased above-ground sequestration through forest plantation and improved forest management can be significant for climate policy. The Kyoto Protocol allows for carbon sequestration by afforestation and reforestation under the Clean Development Mechanism (CDM) within the LULUCF (Land Use, Land Use Change, and Forestry) activities, but this was limited to a small fraction of emissions in 1990. More recently, the need for taking action against carbon releases from forest was recognized in the Paris Agreement. In practice, carbon sequestration has been introduced under different national regulations on GHG emissions and voluntary systems (Peters-Stanley et al., 2012; Kerr, 2013; Goldstein et al., 2014). A majority of these carbon sink offset projects have been incorporated in different voluntary systems, in particular under the Reducing Emissions from Deforestation and forest Degradation (REDD) program, which was created by the United Nations in 2008 to enhance use of carbon sinks (UNFCCC, 2008). Despite these efforts, in 2013 total carbon sequestration accounted for only 0.5% of the total volume of carbon trade (Goldstein et al., 2014; Kossoy et al., 2014).

The potential of carbon sequestration to help meet climate targets depends not only on the size of carbon sink enhancement, but also on the cost compared with that of other measures, in particular fossil fuel reductions. The large body of literature calculating the cost of carbon sequestration shows that the marginal costs of carbon sink enhancement can be considerably lower than those of carbon emissions reduction (see reviews by Sedjo et al., 1995; Stavins, 1999; Richards and Stokes, 2004; van Kooten et al., 2004, 2009; Manley et al., 2005; Phan et al., 2014). Benefits in terms of cost savings from introducing carbon sinks into climate programs have been reported in studies on the cost of meeting global or EU-level climate targets, which conclude that costs can be reduced by up to 40% (e.g., Tavoni et al., 2007; Anger and

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Sathaye, 2008; Bosetti et al., 2011; Michetti and Rosa, 2012; Gren et al., 2012). However, whether these cost savings can be achieved depends on the policy design. Examples of policies are carbon sink as offset within a carbon emissions trading scheme or tax scheme, or compensation payments for afforestation to enhance carbon sink. An important economics question arising is how these policies can be designed so as to foster changes in land users' behavior at minimum cost to society. This study investigated the answers provided in the literature and how carbon exchange systems have been designed in practice.

Any type of policy targeting carbon sequestration has to deal with specific design problems; heterogeneity, uncertainty, additionality, and permanence. Heterogeneity refers to the fact that carbon sequestration of a certain area of land differs between regions because of differences in climate and geo-hydrological conditions, which means that carbon sequestration per unit land depends on the location of the project. This is in contrast to emissions from fossil fuel products, which are quite similar per unit use of, e.g., gasoline. Uncertainty occurs because of stochastic weather conditions affecting biomass growth, and from errors in monitoring and measuring sequestration (e.g., Houghton, 2005). Although there is some uncertainty in the conversion of fossil fuel products to carbon dioxide equivalents, it is negligible compared with that in carbon sequestration (Gren and Carlsson, 2013). Additionality refers to the difficulty in assessing whether the project would be implemented without the policy in question, e.g. whether a piece of land would be converted to forest without a compensation payment for carbon sequestration. Permanence in carbon sequestration during the project period can be hampered by natural causes, such as variations in temperature and precipitation, storms and wildfires, but also by intentional violation of the project rules, e.g., harvesting before the project period expires. Another aspect of permanence is the use of harvested wood products. Carbon sequestration lasts for a longer period when forest products are used for building houses, rather than for heating as bioenergy. These policy challenges for carbon sink projects can be partly addressed by increasing the transaction costs through monitoring and verification of carbon sink enhancement projects (e.g., Cacho et al., 2013), but also through clever policy design, mitigating high transaction costs.

The economics literature on policy design for forest carbon sink enhancement is relatively limited compared with that on the cost of carbon sequestration and cost savings from introduction of carbon sink into climate policy programs, where there are a number of reviews containing over 35 studies (van Kooten et al., 2004, 2009; Manley et al., 2005; Sedjo and Sohngen, 2012; Phan et al., 2014). There are also reviews on policies for carbon sequestration, but they focus on the structuring of policy design without survey of studies (Angelsen, 2008), or on specific forest carbon projects such as REDD + (Hufty and Haakenstad, 2011), or a specific policy instrument such as contract design (Fortmann et al., 2014), or only include a few studies (less than 10) (Capon et al., 2010).

In our view, the main contribution of the present study is that it extends the existing survey literature on policy design. We focus on studies with the explicit aim of analyzing policies directed at improving forest carbon sequestration. This excludes studies investigating side-effects of forestry and agricultural policies on carbon sequestration or release from soil, such as subsidies on bioenergy or taxes on emissions of carbon dioxide (e.g., van Kooten et al., 1995). It also excludes studies calculating the cost of carbon sequestration in terms of necessary compensation to forest owners (e.g. Lubowski et al., 2006; Yu et al., 2014). Studies considering uncertainty in carbon sink where policy makers allocate risk among different abatement and carbon sink options (e.g., Benitez et al., 2007; Fuss et al., 2013; Gren and Carlsson, 2013; Haim et al., 2014) are also excluded, unless they contain explicit policy design for carbon sinks.

When searching for studies with the explicit aim of analyzing policies for forest carbon sequestration, we used common search engines such as Scopus, Thomsen Reuters Web of Science, and Google, and applied key words such as 'forest carbon sequestration', 'policy', 'policy design', 'economics', and 'incentives'. In total, we found 45 studies which address one of the key policy design challenges or describe and/or evaluate carbon policies in practice. However, we cannot exclude the possibility that we overlooked interesting and relevant studies, and the review is thus not exhaustive.

The study is organized as follows. We start by presenting the literature within economics addressing one or several of different types of the specific policy design problems with carbon sink enhancement. Next, studies on carbon sink policies in practice are presented, followed by a comparison and discussion of the main findings in the literature and main design features in practice. The study ends with a brief summary and concluding remarks.

2. Efficient policy design

It can be argued that the policy design for mitigating emissions from combustion of fossil fuel is relatively easy, since the effect on the content of carbon in the atmosphere is the same irrespective of location of the emissions sources. This is not the case with carbon sequestration. The impact of carbon sequestration is site-specific and depends on factors such as soil quality, tree species, and local climate (e.g., Houghton, 2005; Pan et al., 2011). A cost-effective policy design requires policies, such as subsidies for afforestation, to take this heterogeneity into account and adjust to the site-specific sink enhancement. In principle, this would not pose much of a challenge if the policy maker and agents had information on carbon sequestration in each plot.

The complicating factors are associated with different types of uncertainty in carbon sequestration, which can lie with the policy maker and agents, or with asymmetric information, which lies with only one party, usually the policy maker. One uncertainty common to both parties is the variability in weather conditions which affects biomass growth and thereby carbon sequestration in above-ground and below-ground living biomass. Another is the uncertainty created by errors in measuring, monitoring, and verifying carbon sequestration. A third uncertainty factor relates to permanence in a created sink, which can be turned into a source through natural events such as wildfires, storms, and insect and pathogen outbreaks. Asymmetric information on, e.g., baseline emissions and costs of carbon sequestration, is a source of uncertainty for the policy maker but not the agent, who implements a project with full information. Another type of asymmetric information is associated with intentional harvesting of planted trees before expiration of the project period and with the absence of due care to avoid or mitigate carbon reversal from natural causes, which is known by the agent but not the policy maker. These asymmetric allocations of uncertainty between buyer and seller make it difficult to ensure additionality and permanence in carbon sink projects because of the need to measure and establish a baseline and to monitor and verify the carbon sink enhancement by the project under a long period of time.

In the following, we review suggestions in the literature on policy design for managing the challenges associated with heterogeneity and uncertainty in carbon sequestration common to both parties in forest carbon exchange, and asymmetric information with respect to forest carbon cost and sequestration.

2.1. Heterogeneity and uncertainty in biomass sequestration

Instant uncertainty arises from the biological process of carbon sequestration, which depends on stochastic weather conditions, and this uncertainty is common to both the buyer and seller of carbon credits. The literature dealing with this type of uncertainty can be classified into two main categories. One category compares total abatement costs under a system making carbon payments per ton forest carbon with those of systems using other payment bases, such as unit area of land or forest practice (Parks and Hardie, 1995; Kim and Langpap, 2014). The other category regards uncertainty as costly for society and