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Economic value of carbon sequestration in forests under multiple sources of uncertainty

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ABSTRACT

The purpose of this paper is to calculate the value of stochastic carbon sequestration in climate change mitigation when also carbon dioxide emissions from fossil fuels and abatement costs are stochastic. The replacement cost method is used where the value of carbon sink is calculated as associated cost savings from replacement of more expensive mitigation options for achieving a given emission target. Minimum costs with and without carbon sinks are derived with a safety-first approach in a chance constrained programming framework which also accounts for variability in control costs. The theoretical results show that for high enough risk discount, carbon sink is not included in a cost effective mitigation program even when the carbon sink cost is zero. The empirical application to the EU independent commitment of 20% reduction in carbon dioxides shows large variation in carbon sink value depending on risk discount. Under no uncertainty, the value can correspond to 0.33% of total GDP in EU, but it declines due to the uncertainty associated with forest carbon sink and is zero for high probability levels in achieving the target. Thus, whether or not to recommend the inclusion of carbon sink in the EU climate policy depends on the uncertainty of carbon sinks in relation to other sources and on the importance of reaching stipulated emission reduction targets.

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Introduction

The potential value of carbon sequestration as a low cost option for meeting climate change mitigation targets has been notified in several studies (e.g., Stavins, 1999; Pohjola et al., 2003; Lubowski et al., 2006; Bosetti et al., 2009; Michetti and Rosa, 2011). For example, Lubowski et al. (2006) showed that approximately 1/3 of the US carbon abatement commitment would be achieved by forest carbon sequestration in a cost effective solution. Michetti and Rosa (2011) presented results where the inclusion of carbon sink could reduce the cost of meeting European Union (EU) 2020 carbon dioxide (CO_2) mitigation commitment in an emission trading system (ETS) by at least 25%. Despite these results, hesitations remain with respect to the inclusion of carbon sequestration in the EU ETS, the main argument being the stochastic nature of carbon sequestration (European Commission, 2008). This is quite likely the case, but this uncertainty needs to be put into a context of other uncertainties. Costs of reducing fossil fuels, consisting of reductions in associated profits, are stochastic because of, among others, fluctuating input and output prices. The conversion of fossil fuel to carbon dioxide is also uncertain because of differences in conversion factors (Macknick, 2009). Considering that forest areas cover approximately 1/3 of the total territorial area of EU countries, carbon sequestration may play an important role in achieving reduction targets also under conditions of uncertainty. The question is then if the cost advantages of carbon sequestration remain when accounting for all these uncertainties. The purpose of this study is to identify conditions under which carbon sequestration has a positive value under multiple sources of uncertainty and to calculate values of forest carbon sink in the EU commitment of achieving 20% CO_2 emission reduction from the 1990 level by 2020.

In principle, carbon sink constitutes one out of several strategies for mitigating climate change effects. As such, it could be evaluated and compared with other climate change mitigation technologies, such as abatement of emissions from fossil fuels, and the associated value then consists of its relative cost advantages. Such approaches have a long tradition in the large body of literature on evaluation of alternative energy technologies, where costs and benefits have been calculated and compared under condition of different types of uncertainty (e.g., Rothwell, 2007), and learning options (e.g., Siddique and Fleten, 2010). Studies have been estimating cost savings obtained for achieving certain CO_2 emission reduction targets with and without inclusion of carbon sink (e.g., Pohjola et al., 2003; Lubowski et al., 2006; Bosetti et al., 2009). However, in contrast to the literature on evaluation of energy technologies the consideration of uncertainty, which is a specific feature of carbon sequestration due to climate and weather conditions, has rarely been addressed. It is quite likely that the sources of uncertainty often included in the large body of literature on evaluation of alternative energy technologies, such as technology performance, output prices, and production costs, are related also to climate change mitigation technologies. However, the decision rules might be more involved than the consideration of discounted streams of expected net benefits. Climate change mitigation targets are guided by political decisions, such as the Kyoto protocol and EU 2020, and it is quite likely that high probabilities in achieving the targets are of importance (e.g., Stavins, 1997; Barrett and Stavins, 2002).

In this paper we propose a new approach for applying the replacement cost method for assigning values to non-market environmental goods under conditions of multiples source of uncertainty. In order to account for policy makers' relative risk aversion with respect to non-attainment of stipulated targets and aversion against stochastic control costs the safety-first criterion in the framework of chance constrained programming is applied. This approach allows for the separate treatment of aversion against risk in costs and aversion against non-attainment of emission targets. Different variations of the safety-first criterion have a long tradition in economics for dealing with urgent targets, such as minimum food supply (e.g., Tesler, 1955–1956; Pyle and Turnovsky, 1970; Bigman, 1996). In this paper, the approach is combined with a more traditional mean-variance framework in the objective function of minimizing total cost, which accounts for aversion against uncertainty in abatement costs (e.g., Luenberger, 1997). This combined approach is applied to the EU target of reducing CO_2 by 20% compared to the 1990 level, which is to be achieved at the latest in 2020.

In our opinion, the main contribution of this paper is the application of the replacement cost method in a safety-first setting in terms of chance constraint programming combined with portfolio analyses