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The potential and cost of increasing forest carbon sequestration in Sweden

Jinggang Guo, Peichen Gong*

Centre for Environmental and Resource Economics, Department of Forest Economics, Swedish University of Agricultural Sciences, SE-901 83, Umeå, Sweden

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ABSTRACT

This paper examines the potential and the cost of promoting forest carbon sequestration through a tax/subsidy to land owners for reducing/increasing carbon storage in their forests. We use a partial equilibrium model based on intertemporal optimization to estimate the impacts of carbon price (the tax/subsidy rate) on timber harvest volume and price in different time periods and on the change of forest carbon stock over time. The results show that a higher carbon price would lead to higher forest carbon stocks. The tax/subsidy induced annual net carbon sequestration is declining over time. The net carbon sequestration during 2015–2050 would increase by 30.2 to 218.3 million tonnes of CO_2, when carbon price increases from 170 SEK to 1428 SEK per tonne of CO_2. The associated cost, in terms of reduced total benefits of timber and other non-timber goods, ranges from 80 SEK to 105.8 SEK per tonne of CO_2. The change in carbon sequestration (as compared with the baseline case) beyond 2050 is small when carbon price is 680 SEK per tonne of CO_2 or lower. With a carbon price of 1428 SEK per tonne of CO_2, carbon sequestration will increase by 70 million tonnes of CO_2 from the baseline level during 2050-2070, and by 64 million tonnes during 2070–2170.

Introduction

Using forests to reduce the accumulation of atmospheric CO_2 has gained a growing interest in scientific and policy discussions. The world's forests cover 31% of global land area and store an estimated 296 Gt of carbon in their biomass alone (FAO, 2015). Forests play a significant role in the global carbon cycle, since they act as both major contributors and sinks of atmospheric CO_2. IPCC (2007) assessed that forests could offer an effective way to mitigate climate change through sequestration of carbon.

Forests carbon sequestration has the characteristics of a public good, and thus is likely to be under-produced due to the lack of economic incentives for forest managers to take into account the carbon sequestration benefits in their managerial decisions. As pointed out by Sedjo (2001), forest carbon sequestration can be increased by adopting a number of measures, such as creating more forests, reducing the conversion of forests to other land uses, adopting growth enhancing silviculture practices, and reducing the loss of forest biomass caused by nature disasters. Whether or not, and to what extent forest carbon sequestration should be increased depend on the marginal cost of doing so.

About 70% of the land area of Sweden is covered by forests, extending to over 28 million hectares, of which 23.2 million hectares are considered productive forestland. Forest growth as well as the standing volume has been steadily increasing since the 1920s when the first national forest inventory was conducted. The current annual growth exceeds 120 million m^3 and the total standing volume amounts to over 3 billion m^3 (Swedish Forest Agency, 2014). Forest growth in Sweden is expected to maintain the increasing trend in the foreseeable future (Rosvall, 2007; Swedish Forest Agency, 2008, 2014). Compared with the total emission of GHGs in Sweden, which is about 58 Gt CO_2 equivalents per year (Eurostat, 2015), the physical potential to use forests in Sweden to sequester carbon is huge. However, timber production is an important objective of forest management in Sweden. To what extent forest owners are willing to use the physical potential of forest carbon sequestration for the purpose of climate change mitigation depends on the benefit and cost of providing this service.

The purpose of this paper is to assess the potential and the cost of stimulating forest carbon sequestration through a carbon tax/subsidy scheme. To this end, we will modify a timber market model by including monetary incentive to forest owners for increasing carbon sequestration and use the model to simulate

* Corresponding author.
E-mail address: peichen.gong@slu.se (P. Gong).

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future timber harvest and forest carbon storage, as well as the benefits of timber and other non-timber goods (such as biodiversity, recreation and so on), associated with different carbon prices (the tax/subsidy rate). This analysis covers most of the productive forestland of the country. The results provide us estimates of the potential and the cost of increasing forest carbon sequestration through a carbon tax/subsidy scheme. The remainder of the paper begins with a review of related previous studies, followed by a brief description of the model we employed. The estimation results are presented and discussed in Section 4. The final section summarizes the main findings and discusses potential extensions of the study.

Previous studies

The cost of carbon sequestration has been the subject of numerous studies in the field of forest economics. Richards and Stokes (2004) presented a comprehensive review of the earlier works on this topic. They synthesized the results of various studies and concluded that the cost could range from $10 to $150 per tonne of carbon to fix roughly 2 Gt carbon per year. The markedly varying costs were confirmed by Stavins and Richards (2005) and van Kooten et al. (2009).

One factor contributing to the wide range of cost estimates is the different models applied, which can be grouped into three broad categories, namely, bottom-up models, econometric models, and sector optimization models (Sohngen 2010). Analyses using bottom-up models (e.g., Parks and Hardie, 1995) concentrate on measuring the operational costs of and the amount of carbon sequestered by different forestry projects. Effects on the prices of forest products as well as the potential externalities of the projects under examination usually are ignored in such analyses. Econometric models are widely used to identify the preferences of landowners when confronted with alternative land use options. Forest product prices are determined endogenously and used to estimate the relative returns and to assess the probability of land use changes (see, e.g., Lubowski et al., 2006). By using empirical data, econometric approaches could provide reliable predictions of land use changes in response to different policy options. Forest sector optimization models (e.g., Sohngen and Mendelsohn, 2007) attempt to optimize the management of forests under different circumstances and, therefore, are capable of taking into account the behavioral response to changes in a wide range of socioeconomic factors, such as population and income growth. An excellent review of the different types of models can be found in Latta et al. (2013).

Another factor accounting for the varying costs is the type of measures used to increase forest carbon sequestration. Much effort in previous studies has been placed on afforestation, reforestation, and avoided deforestation, partly because of the fact that only afforestation and reforestation qualify for carbon sink projects under the Kyoto Protocol (Smith, 2002). For instance, Sohngen and Sedjo (2006) simulated the forest and land use decisions in response to exogenously given carbon price paths at the global level, and found that most carbon sequestration would originate from afforestation and reduced deforestation in tropical and temperate regions. They also stressed that a higher sequestration level can be achieved by implementing rising carbon price policies. Several subsequent studies (e.g., Kindermann et al., 2008; Rose and Sohngen, 2011) provided similar results.

In addition to the consideration of land-use change as a possible means of reducing CO_2 emissions, many studies focus on the role of changing forest management practices in enhancing carbon uptake. For countries with relatively stable land use patterns and large endowments of forests, this option seems more applicable. Changing rotation age and thinning scheme are two commonly studied methods for managing forests to mitigate climate change. For instance, Hoover and Stout (2007) concluded that, by altering the stand structure, thinning could promote timber growth and strengthen the adaptive capacity to withstand disaster risks and subsequently favor carbon sequestration. Liski et al. (2001) found that longer rotations could favor carbon sequestration at the cost of delayed timber revenues. The primary focus of these studies is how forest management practices should be changed in order to increase carbon sequestration (to the optimal level). As such, they generally do not provide estimates of the cost of carbon sequestration. There are exceptions, however. One example is Im et al. (2007). They examined the optimal management intensities and regeneration methods under a range of carbon tax levels. Their results show that the marginal cost of increasing carbon sequestration by private forests in Oregon is comparable with that of afforestation projects in some parts of the United States.

Several studies show that increasing forest sequestration can be a cost-effective option to limit CO_2 emissions within the EU (see, e.g., Gren et al., 2012; Münnich Vass, 2015). These studies optimize forest carbon sequestration from a social planer's perspective, assuming that forests shall be used to minimize the total cost to reach a given emission target. A few studies have estimated the potential and the cost of increasing forest carbon sequestration when forest management decisions lie in the hands of landowners. Backéus et al. (2005) used a linear programming model to determine the optimal balance between timber production and carbon sequestration when forest owners get paid for carbon sequestration and pay for CO_2 emission resulted from timber harvest. Their results from a case study, which covers 3.2 million ha forests in northern Sweden, show that when carbon price is zero the average annual rate of sequestration (over a period of 100 years) is 1.48 million tonnes of carbon and the net present value (NPV) of timber production is over 40 billion SEK. When carbon price approaches 1000 SEK/tonne of C (273 SEK/tonne of CO_2), timber harvest in the region reduces to zero, the NPV of timber production diminishes, and the average annual sequestration rate increases to the maximum level of 2.05 million tonnes. In the model of Backéus et al. (2005) timber prices are exogenous. In a large-scale analysis, reduction in timber harvest may lead to significant increases in timber price, which presumably would affect forest owners' management decisions and hence the effects of carbon tax/subsidy on carbon sequestration. Clearly, one should not generalize the results of Backéus et al. (2005) and predict that a carbon price of 1000 SEK/tonne of C would cause all forest owners in Sweden to stop harvesting.

Sjølie et al. (2013) used a partial equilibrium model, which accounts for the impacts of price changes, to assess the increase in forest carbon sequestration in Norway that could result from a carbon tax/subsidy policy with varying carbon prices. Their result shows that a carbon price of €100 per tonne CO_2 would substantially enhance forest management intensity and reduce harvest volume, thereby lead to a significant increase in carbon sequestration. Because forest regeneration investment in Sweden is already very high,[1] we expect that a carbon tax/subsidy policy would result in a much lower increase in forest carbon sequestration in Sweden than in Norway.

Method

The model

The model used in this study is an extension of the Swedish Timber Market Model (STIMM) presented in Gong and Löfgren (2003)

[1] The average regeneration cost in 2012 is about 1000 €/ha (Swedish Forest Agency, 2014).