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Analysis

Afforestation and timber management compliance strategies in climate policy. A computable general equilibrium analysis

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A B S T R A C T

This paper analyzes the role of forest-based carbon sequestration in a unilateral EU27 emissions reduction policy under a Global Computable General Equilibrium (CGE) framework. Forestry mitigation is introduced into the model relying on carbon sequestration curves provided by a global forestry model. The structure of the original CGE is extended to consider land use change and timber supply effects, resulting from the use of forest sinks to reduce carbon emissions. Results show that afforestation and timber management could lead to substantially lower policy costs. By using forest-carbon sinks it is possible to achieve the 30% emissions reduction target with an additional European effort of only 0.2% of GDP compared with the cost of a 20% emissions reduction without forestry. Carbon price is also reduced, by approximately 30% in 2020. European forest-carbon sequestration may have, however, the perverse effect of increasing timber production in areas of the world which already have high deforestation rates. A sensitivity analysis on main parameters confirms the robustness of our results.

1. Introduction and Motivation

Forests provide several economic and environmental services (Schulze et al., 2000), such as water flow regulation, recreation, esthetic values, and carbon sequestration. Although a detailed carbon plan has not yet been articulated in any specific legislation, the direction of the international debate on forest-carbon intends to strengthen the already existing policies on forestry, and to extend its contribution. In addition to the next phase (2013–2020) of the European Unions' Emissions Trading Scheme (EU-ETS), international forest-carbon has been central for deliberations to the climate change policies proposed in Brazil, which launched the Amazon Fund in 2008, in Australia, in Japan, and in the United States. Aiming to enhance the use of forest-carbon sinks, in 2008, the United Nations created the Reducing Emissions from Deforestation and Forest Degradation Program (UN-REDD) and recognized the role of conservation, and sustainable management of forests to enhance forest-carbon stocks in developing countries. In 2009, the Copenhagen Accord clearly stated the need to develop mechanisms to reward sustainable land-use practices developing forest-carbon sequestration. Accordingly, the range of climate mitigation options of the forestry sector was expanded through the REDD+ mechanism, which is based on a payment system for developing countries that reduce emissions by avoiding deforestation and enhances forest-carbon stock through sustainable management.[1] The REDD+ mechanism has been acknowledged, within the international debate, as a key target for a future binding agreement on climate change mitigation. While the international debate has been centered on avoided deforestation (AD), the annual volume of transaction for afforestation (AR) projects, in both voluntary and compliance markets have been growing in time, and it surpasses the value of AD projects. Today it represents 60% of the total volume of forest-based projects, corresponding to approximately 8 Mt CO_2 (Hamilton et al., 2010).[2]

An extensive number of studies have estimated costs of forest-carbon sequestration, which highly depend on different assumptions, parameters, methodologies, and definitions. Richards and Stokes (2004) provide a useful summary of these estimates. After describing the major differences among the surveyed models, it concludes that carbon cost estimates range from 26–550 USD per t/CO_2. Similarly, van Kooten and Sohngen (2007) more recently report that costs of

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[1] The sum of afforestation, reduction in deforestation (REDD), and forest management is referred to as REDD+ activities.

[2] IPCC, SRES (2000) forecasts that 8–10% of the forest soil will be afforested–reforested in the tropics by 2050, leading to an estimated uptake of 40–199 Gt of Carbon.

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sequestering forest-carbon are around 3–280 USD per t/CO_2 and that Europe is the highest cost region. Both studies have identified three different approaches for cost analysis: bottom-up engineering cost studies,[3] econometric studies of foresters' revealed preferences,[4] and sector optimization models.[5] The first set of models does not consider economic agents' responses when assessing the cost-effectiveness of a specific forest-investment activity. The second approach uses observed landowners' choices on land use to derive a relationship between land use change decisions and prices in the agricultural and forestry sectors. Finally, the third approach has the advantage of endogenizing agricultural and timber prices as a function of landowners' decision. Although most of these studies are not directly comparable, they share the conclusion that forestry provides cost-efficient mitigation opportunities, suggesting that significant amounts of carbon can be sequestered for less than 50$ per ton (see also Rose et al., 2008; Lubowski et al., 2006).

Linking a forestry model with a global climate economic model Sohngen and Mendelsohn (2003) and Tavoni et al. (2007) have concluded that forestry can contribute for around 1/3 of total CO_2 abatement. These studies, however, provide a unified assessment of the forest sector, without disentangling the individual contribution of different forestry practices.

In contrast, researchers who have focused on afforestation–reforestation (AR) and timber management (TM) potential to reduce CO_2 emissions have usually dealt with specific geographic areas in the US and have normally relied on a partial equilibrium view, ignoring the general equilibrium aspects of the problem.[6]

In this paper we use a global computable general equilibrium model (CGE), to explore both direct and indirect socio-economic effects of AR-TM in Europe. The policy exercise assumes that Europe independently commits to reduce CO_2 emissions below 1990 levels, by 20% and 30% in 2020.

Similarly to Sohngen and Sedjo (2006) we do not restrain our analysis to afforestation practices but consider also timber management (TM) as an additional carbon abatement option. As a result, we have modified the original Intertemporal Computable Equilibrium System (ICES) model to capture the different impacts resulting from these two activities.

Following the distinction in Richards and Stokes (2004), we investigate "secondary", other than "primary" costs and benefits of AR-TM. In particular we examine the changes in *policy costs, carbon sequestered*, *land-use change* (converting timber-forests or agricultural land into carbon-forest land), as well as *land* and *timber market prices*. Finally, we observe the magnitude of leakage for the case of AR activities, often neglected by the literature and addressed only to the AD practices. By providing a multi-country, multi-sectoral account of the world economy, in which national economies are represented as a system of markets interconnected by domestic and international flows of input, goods and services, CGE models are particularly apt to analyze carbon leakage.[7]

We believe that our investigation contributes to the current discussion on carbon sinks by analyzing the role of forests in Europe under a domestic climate change mitigation policy. We add to the literature by exploring global effects and by considering the "higher order" or general equilibrium outcomes determined once all adjustment mechanisms at play in the economic system have occurred. In fact, as CGE models are characterized by market interdependence, they are particularly pertinent to capture reallocation effects affecting the entire economic system.

The paper is organized in 5 remaining sections. Section 2 briefly presents the model. It also describes the main changes implemented in the model and the methodology used to derive the cost curve. Section 3 draws the key results while Section 4 develops a sensitivity analysis on main coefficients. Section 5 concludes. In Appendix A, a more detailed description of the ICES model is provided.

2. Methodology

We rely on the ICES model (Bosello et al., 2007), a global CGE setting entailing a multi-country and multi-sectoral description of the world economy.[8] The most refined version of this model develops a recursive dynamic sequence of static equilibria, under myopic expectations, which are interlinked by the process of capital and debt accumulation as described in Eboli et al. (2010). In the present study we employ a simplified static structure of the ICES model, projecting all the systems from 2001 (calibration year) to 2020, which grow in only one-time step. In Appendix A, we offer a more detailed description of the static version, some of which are common to the dynamic one.

2.1. Modeling Afforestation and Timber Management Effects

Forest mitigation options for Europe are introduced into ICES by adding a forest-based carbon sequestration curve provided by Sohngen (2005). This study uses a global forestry and land-use model to derive marginal costs of carbon sequestration for selected world regions under alternative constant carbon prices for the period 2005–2105. In such partial equilibrium framework, carbon sequestration results from optimal responses to choices over land use (AR, and AD), and changes in forest and timber management (TM). More specifically, marginal cost curves are estimated following a multi-step procedure. Initially, a baseline carbon storage refers to the case with no climate change and no incentives to store carbon. Then, a range of constant prices is included to create counterfactual scenarios. Cumulative carbon gains are derived as the difference in stocks between the baseline carbon storage and these counterfactual scenarios for the period 2005–2150 in 10-year time-steps. Further calculations allow plotting an annual equivalent of carbon (discounted at a rate of 0.05) against the carbon price (assumed the same for each region), therefore obtaining the European curve that is introduced in the ICES model (see Fig. 1).

Given that the activities of AR and TM impact land use allocation and timber market flows differently, we distinguish between carbon sequestrations provided by afforestation and changes in timber management. In fact, according to Sohngen (2004), these two forestry mitigation options encompass total carbon storage provided by European forests.

As curves in Sohngen (2005) provide only total carbon sequestration without disentangling the contribution of different forestry activities, we split it into AR and TM using the information provided in Sohngen and Sedjo (2006), and Sohngen (2004). According to Sohngen and Sedjo (2006), the total amount of carbon stored by forests in temperate regions can be divided into two parts: 34–40% sequestered via AR (devoting more land to forests) and 54–63% stored via change in TM (changing forest rotation). In this analysis we closely follow Sohngen (2004). According to these authors, at a constant carbon price of $100 per ton of carbon, the percentage of carbon stored in Europe as a result of land use change (AR) is 40%, while the remaining 60% is due to TM.[9] Once forest-carbon sequestration is divided into its two components we modify the model assuming the following hypotheses:

[3] See among others Moulton and Richards (1990); and van Kooten et al. (2000).

[4] See, Stavins (1999); Newell and Stavins (2000); and Stavins and Richards (2005).

[5] See, Sohngen and Mendelsohn (2003); Kindermann et al. (2008); and Dixon et al. (2009).

[6] See for example, Nordhaus (1991); Parks and Hardie (1995); Alig et al. (1997); Stavins (1999); and van Kooten et al. (2000).

[7] For more details on the leakage assessment within CGEs see for example, Peterson and Schleich (2007); Burniaux and Martins (2000); Babiker (2005); Babiker and Rutherford (2005); Bohringer et al. (2010).

[8] The ICES model has been developed at the Fondazione Eni Enrico Mattei (FEEM) and its main features are described at the following website: http://www.feem-web.it/ices/.

[9] These values refer to their 5th scenario, which is the closest to ours.