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# Pricing forest carbon: Implications of asymmetry in climate policy

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ABSTRACT

Using an integrated assessment model, we examine the implications of climate policies that do not fully recognize forest carbon. Specifically, we first investigate the impact of an asymmetric policy that recognizes carbon emissions from fossil fuels while fully ignoring forest carbon. Next, we investigate the relative importance of not recognizing emissions from a reduction in the stock of forest biomass compared to not recognizing sequestration from the growth of forest biomass. We show that asymmetric carbon policies lead to lower levels of welfare, as well as higher emissions and carbon prices. This occurs because the forest resource will be allocated inefficiently under these carbon policies. Broadly, we find that when the social planner does not account for emissions or sequestration from the forest, the planner will set bioenergy levels that are too high and afforestation and avoided deforestation levels that are too low. Our results further reveal that not recognizing forest emissions leads to larger welfare losses than not recognizing sequestration.

## Introduction

This paper uses an integrated assessment model that accounts for the dynamics of the forest, to investigate the effectiveness of climate policy when forest carbon emissions and sequestration (negative emissions) are not recognized, or only partially recognized, by policymakers. Specifically, we consider two asymmetric carbon policy regimes. In the first regime, which resembles the current state of climate policy, policymakers take into account carbon emissions from fossil fuel but do not take into account emissions and sequestration from forests. In the second regime, we establish the relative importance of not recognizing emissions from forests compared to not recognizing sequestration from forests.

Recently, policymakers have begun to coalesce around the idea of pricing carbon. In theory, a dynamic Pigouvian tax, which amounts to the marginal cost of carbon in the optimal emissions path, could fully internalize the adverse effects of carbon emissions. As all sources of carbon emissions are equal in terms of climate impact, the carbon price should be universal. However, a global carbon price including all emissions is far from reality. In practice, policymakers have favored levying taxes on fossil energy, while taxation of other emissions, such as those from bioenergy production, have been to a large extent disregarded. As theoretically derived by Lundgren et al. (2008), this asymmetry in carbon policy leads to a distortion of the price differential between fossil energy and bioenergy which results in too high levels of bioenergy being produced.

At the heart of this debate is the question of whether bioenergy production is carbon neutral. Previous literature has shown that treating bioenergy as carbon neutral will underestimate the negative climate impact of bioenergy production (e.g., Searchinger et al., 2009; McKechnie et al., 2010; Cherubini et al., 2011). This occurs because bioenergy production is not carbon neutral in the short run. The release of carbon from bioenergy production is instantaneous, while sequestration via biomass growth occurs over time. Carbon released from harvest to produce bioenergy initially exceeds the avoided fossil fuel emissions and temporarily increase the total emissions (McKechnie et al., 2010). Lundgren and Marklund (2013) show that policies that rely on the carbon neutrality assumption are misleading and can lead to a reduction in welfare.

It is possible that certain technologies will permit avoiding emissions from bioenergy even in the short run. Specifically, bioenergy production in combination with carbon capture and storage (CCS), can make bioenergy carbon neutral and even achieve negative emissions (Kraxner et al., 2003; Azar et al., 2010; Fuss et al., 2013; Van Vuuren et al., 2013). Favero et al. (2017) show that this technology can be used together with traditional sequestration policies to reduce carbon emissions efficiently. With a dynamic forest sector model, they show that using forests for bioenergy production leads to more intense forest management and fast-growing trees while a traditional sequestration policy leads to more natural forests and larger trees. Nonetheless, forest biomass with current CCS technology only becomes a cost-efficient strategy at high carbon prices (Favero and Mendelsohn, 2014;

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Humpenöder et al., 2014), and there are still great uncertainties surrounding the technology and its storage potential (Van Vuuren et al., 2013). This suggests that both emissions and biomass sequestration should be taken into account in climate policy given the current technology.

As highlighted by Lundgren et al. (2008), climate policy should encompass not only taxing all emissions, including those from bioenergy, but also subsidizing at the same rate sequestration from forest growth. From the bioenergy policy debate, it is thus clear that policies that aim to price carbon risk falling short in two respects. First, by limiting the scope of sources of emissions. Second, by encouraging efforts to reduce emissions, while not valuing efforts to increase carbon sequestration.

Under the assumption that policymakers fully recognize forest carbon, the forest can play a key role in reducing carbon emissions both through fossil-fuel substitution and carbon sequestration in biomass. In a review of sequestration cost studies, Richards and Stokes (2004) conclude that different forestry practices can significantly increase carbon sequestration and cost-effectively reduce atmospheric carbon. Among different sequestration options, avoiding tropical deforestation proves to be one of the most effective sequestration options (e.g., Sohngen and Mendelsohn, 2003; Gullison et al., 2007; Tavoni et al., 2007; Kindermann et al., 2008; Sohngen et al., 2009; Bosetti et al., 2011).

However, as highlighted by another strand of the literature, there are various synergies and trade-offs between policies that incentivize the use of biomass for fossil-fuel substitution and those to increase the stock of biomass for carbon sequestration (e.g., Lecocq et al., 2011; Kallio et al., 2013). It is therefore of particular importance to analyze the role of the forest and asymmetric policy regimes, in a framework that accounts for these trade-offs as well as the interactions between the various climate policies.

In this paper, we use such a framework to develop the intuition of the bioenergy literature as discussed by Lundgren et al. (2008). Specifically, we extend the discussion in two ways. First, we use an integrated assessment model that accounts for the dynamics of the forest. This framework allows us to provide estimates of the price of carbon under optimal and asymmetric policy regimes. Second, we take the discussion of asymmetric carbon policy to a broader category of forest controls, which besides bioenergy harvest also includes avoided deforestation and afforestation. These controls are especially important as the amount of forestland is directly related to the potential to increase forest biomass and thus bioenergy harvest. More broadly, including these controls, allows us to increase the scope of the analysis, as we are now able to study the dynamics and the interactions between various controls capable of altering the stock of forest biomass.

This paper is part of the broader literature that uses more comprehensive models to study land-based mitigation with a wider range of land use activities. The literature robustly shows that climate stabilization costs could be lowered by including land-based mitigation. For example, Rose et al. (2012) analyze four integrated assessment land models and concludes that agriculture, forestry, and bioenergy can be leveraged to reduce emissions. While there is general agreement on the importance of including land-based mitigation in climate policy, there is an ongoing discussion on the relative effectiveness and interactions of the different strategies. Especially discussed in this literature is the potential of bioenergy to reduce carbon emissions.

The potential of bioenergy to reduce carbon emissions essentially depends on the source of biomass and its effects on land use. A large increase in the demand for forest biomass to produce energy will increase the value of timber and generate more investments in forestland. While increased demand for bioenergy increases harvests, net emissions may be reduced because the overall sequestration rate will also increase due to an increase in forestland (Havlík et al., 2011; Daigneault et al., 2012; Sedjo and Tian, 2012). Analogously, if crops are the source of bioenergy, increase in the relative value of cropland will decrease the forest sequestration (Searchinger et al., 2009; Wise et al., 2009). Unless a comprehensive land-use policy is in place, large-scale production of bioenergy crops will increase the competition with other land use activities and result in considerable emissions from land-use change (Popp et al., 2011, 2012; Wise et al., 2009; Reilly et al., 2012; Calvin et al., 2014).

In this analysis, we focus on the forest as a source of bioenergy, carbon emissions, and sequestration. We investigate the impact of two types of asymmetric carbon policy regimes by using an extended version of the FOR-DICE (Eriksson, 2015). In this model, the social planner maximizes welfare by choosing the level of forest controls in addition to savings and energy abatement. In the first asymmetric policy regime, the social planner does not account for forest carbon emissions or sequestration when choosing the level of the forest controls. In the second regime, we investigate two variations: in the first variation, the planner accounts for sequestration from forests but not for emissions. In the second variation, the planner accounts for emissions from forests but not for sequestration. These regimes are compared against the optimal case where the social planner fully recognizes all sources of emissions in the model.

This study provides three main findings. First, asymmetric carbon policy regimes lead to considerable distortions in the allocation of forest resources. Specifically, not accounting for emissions or sequestration from forests will lead to levels of bioenergy harvest that are too high, and to levels of afforestation and avoided deforestation that are too low. This inefficient allocation leads to the lowest level of welfare, the highest emissions, and the highest carbon prices. Second, while it is always preferable to account for both forest emissions and sequestration in carbon policy, we can avoid the largest welfare losses, and achieve close to optimal levels of total emissions, by just accounting for forest emissions. Third, our back of the envelope calculation on the optimal forest tax and subsidy scheme indicates that the cost of the subsidy would outpace the revenue from taxing forest emissions. However, this subsidy could be financed by a broader tax policy that also includes revenues from taxing fossil fuels.

The paper is organized as follows: Section 'The integrated assessment model' briefly describes our model. Section 'Results' presents the scenarios and discusses the main findings. Finally, Section 'Conclusion and policy implications' offers concluding comments and suggests directions for future research.

## The integrated assessment model

This paper uses an extended version of the integrated assessment model FOR-DICE (Eriksson, 2015).[1] The FOR-DICE is a globally aggregated optimization model of the climate and the economy that includes the forest both as a source of renewable energy and as a carbon sink. The forest in the model is represented in a simplified manner and does not include global timber markets, nor timber prices. This simple optimization framework allows us to analyze implications of asymmetries from not recognizing forest carbon in climate policy. In the model, the global forest is composed of three stocks of forest biomass controlled by bioenergy harvest, avoided deforestation, and afforestation. In this section, we briefly describe the main features of the framework and the channels of forest carbon emissions. The reader is referred to Eriksson (2015) for further details on the model.

FOR-DICE is a one region neoclassical economic growth model where carbon emissions, via the global mean temperature, affects the economic output through a damage function. Total carbon emissions come from fossil carbon and forest carbon net of sequestration. The objective function of the FOR-DICE is the present value sum of all future

[1] The FOR-DICE model by Eriksson (2015) is an extension of the DICE-2007 model by Nordhaus (2008). The key extension includes integration of the global forest biomass and the introduction of forest controls.