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Climate and forests: The tradeoff between forests as a source for producing bioenergy and as a carbon sink[☆,☆☆]

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ABSTRACT

Forest harvests are a possible source of second-generation wood-based bioenergy. The carbon stored in the forest is highest when there is little or no harvest from the forest. Increasing the harvest from a forest, in order to produce more bioenergy, may thus conflict with the direct benefit of the forest as a carbon sink. We analyze this conflict using a simple model where bioenergy and fossil energy are perfect substitutes. Our analysis shows how the social optimum will depend on the size of the climate cost, and how the social optimum may be obtained by suitable taxes and subsidies.

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1. Introduction

An increasing concern for climate change has made many countries consider biofuel and other forms of bioenergy as an important alternative to fossil energy. However, concerns have been raised about the use of bioenergy, at least of first-generation food-crop-based biofuels. The critique has partly been due to the upward pressure such biofuel production has put on food prices (Chakravorty et al., 2008; Bahel et al., 2013; Hassler and Sinn, 2012). This type of biofuel has also been criticized for the greenhouse gas emissions related to growing and processing. Obvious sources of emissions from biofuel production include the use of fertilizer when growing energy crops (Crutzen et al., 2008), as well as the use of fossil energy in the harvesting and processing of the crops (Macedo et al., 2008). A second problem with the production of bioenergy is that it may cause carbon emissions due to direct and indirect land use changes (see e.g. Searchinger et al., 2008; Berndes et al., 2010; Andrade de Sá et al., 2013). This is true both for conversion of grazing land and forest land to land for producing crops for bioenergy. For both types of land the land conversion may give a loss of carbon stored in the soil, and for forest land there may in addition be a loss of forest carbon stocks.

An alternative to converting grazing land or forest land into land for growing suitable crops for bioenergy production is to use the harvests from standing forests to produce bioenergy. However, wood-based bioenergy from standing forests is not unproblematic from a climatic point of view. The carbon stored in the forest is highest when there is little or no harvest from the forest. Hence, increasing the harvest from a forest in order to produce more bioenergy may conflict with the direct benefit of the forest as a sink of carbon.

Wood-based bioenergy may take many forms, including e.g. raw firewood, processed charcoals, and pellets. The possibility of producing liquid biofuel from cellulosic biomass may also be a promising alternative to using food crops (Hill et al., 2006). The common denominator is that there is an underlying biological process that will remove carbon from the atmosphere and store it in biological materials. To analyze the climatic effects of wood-based bioenergy from standing forests in more detail, we present a simple but general model of this biological process and the interactions between the gradual forest growth inducing depletion of atmospheric carbon and the instantaneous emission from energy consumption.

We present our model in Section 2. In this model bioenergy and fossil energy are assumed perfect substitutes. The cost of producing fossil energy is assumed increasing in cumulative extraction, so that in the long run fossil energy production will tend to zero. In Section 3, we derive the properties of the social optimum, and show that there will exist a phase prior to the non-fossil era when bioenergy and fossil energy will both be produced. Our analysis shows how the social optimum will depend on the social cost of carbon; henceforth called the climate cost. In particular, we show that the long-run carbon stock contained in the forest is higher the higher is the climate cost. The long-run output level of bioenergy may be either increasing or declining in the size of the climate cost, depending both on the size of this cost and on the cost of producing bioenergy.

In Section 4, we briefly describe the unregulated market economy, and show how the equilibrium in such an economy differs from the social optimum. In Section 5, we show that the equilibrium of the market economy will coincide with the social optimum if all carbon emissions to the atmosphere are taxed at a rate equal to the size of the climate cost, and carbon sequestration through forest growth is subsidized at the same rate. If policy is restricted to taxes on the two types of energy, the first-best may nevertheless be achieved in our simple model. The tax rate on fossil energy should in this case be equal to the size of the climate cost, while the tax rate on bioenergy will generally differ from the fossil energy tax rate. If there is a binding political constraint on how high the tax on fossil energy can be, this constraint may affect the (second-best) optimal tax on bioenergy. In many recent papers exploring the interactions between renewable and non-renewable energy sources (Hoel, 2012; Grafton et al., 2012; Gronwald et al., 2013), the focus is primarily on how policy measures may affect the extraction path of the non-renewable energy source. In this paper the focus is instead on the optimal supply of bioenergy, and how to achieve this with policy measures.