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Price of CO_2 emissions and use of wood in Europe

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ABSTRACT

In this study, we examine the effects of the price for fossil fuel CO_2 emissions on the use of wood in Europe. In particular, we assess the economic potential to substitute wood for coal in large scale heat and power production. We also review the impacts of increased energy wood usage on the forest industry and roundwood prices. The analysis is conducted with the European Forest and Agricultural Sector Optimization Model. We consider three scenarios, where carbon price remains at 20 €/tCO_2, increases to 50 €/tCO_2, or increases to 110 euro/tCO_2 by 2040. It seems that a carbon price higher than 20 €/tCO_2 is required to increase wood based energy production. At prices below 50 €/tCO_2, energy wood consists mainly of forest chips, recycled wood, bark, and black liquor. At the carbon price of 50 €/tCO_2, the use of wood for energy begins to compete with the use of wood in the forest industry. At the price of 110 €/tCO_2, roughly one third of wood used in large scale heat and power production would also be suitable for material use. Even then, the contribution of wood based energy in reaching the EU RES target is modest, since the availability of wood limits its increased use in energy production.

1. Introduction

1.1. Background

The use of woody biomass as an energy source is expected to increase in Europe in the future. The most important reasons for this are the need to reduce the dependency on fossil fuels and to curb greenhouse gas emissions in order to mitigate climate change. The EU policy for Renewable Energy Sources (RES) and the emission trading system for greenhouse gases (ETS) have been implemented to that end. The RES policy requires that 20% of the energy consumption in the EU should be produced using renewable energy sources by 2020. Wood based fuels are renewable, and they have been classified as carbon neutral.

The logging residues and recycled wood form a largely unused reserve of energy in many European countries (Hetsch, 2008; EUWOOD, 2010). In addition, there is potential to increase the use of roundwood for energy in a sustainable manner and without major impacts on the wood supply for the forest industries. Currently, the growth in European forests exceeds the harvests. At least in some countries, such as Finland and Norway, the use of wood in the manufacturing of some traditional pulp and paper products has declined. This is due to the tightened global competition in the product markets, further strengthened by the fact that the demand for some printing and writing papers has stopped growing or even turned into decline in some countries following the information technology revolution in the communications and media sectors (Hetemäki and Nilsson, 2005). This may make room for the energy sector to enter the roundwood market.

1.2. Prior studies

Several studies, for example, Asikainen et al. (2008), Hetsch (2008), and EUWOOD (2010), address the physical potential to increase the use of wood in a particular region or country. Assessing the economic potential is more challenging, because it requires determining how the forest industry adjusts to the competition over woody biomass with the energy sector. In the long run, even forest management might adjust to the new market situation. On the other hand, the demand for wood fuel is affected by factors such as the demand for heat and power, prices of competing fuels, available technologies of converting primary energy forms to secondary, and various taxes, subsidies and regulations set by governments. Few studies address more than one of these aspects simultaneously. In most studies, price, demand, or supply of wood fuels is an exogenous input.

European Environment Agency (2006) and Moiseyev et al. (2011) consider the potential supply of woody biomass from the European forests at alternative exogenous price levels of energy wood. Raunikar et al. (2010) study the global development of roundwood prices and forest industry production in a situation where the demand for fuelwood is fixed to evolve as described in the scenarios of the Intergovernmental Panel of Climate Change. Some country specific studies also exist, for example, Bolkesjø et al. (2006), Trømborg et al. (2007), Trømborg and Solberg (2010), Sjølie et al. (2010) and Bright et al. (2010) for Norway, Schwarzbauer and Stern (2010) for

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Austria, Ince et al. (2011) for the U.S., Lecocq et al. for France (2011) as well as Ranta et al. (2007) and Kallio et al. (2011) for Finland.

While the studies focusing on the forest sector do not usually elaborate what happens in the energy sector, studies focusing on the energy sector tend to ignore those developments in the forest sector that affect the supply of wood fuels. Odenberger et al. (2009) examine the impacts of enforcing CO_2 emission reductions in electric power production in Northern Europe, with and without carbon capture and storage. They assume a fixed price for biomass and do not consider the option of co-firing biomass with coal. Hansson et al. (2009) estimate that the technical potential to co-fire biomass with coal in power production ranges from 140 to 250 TWh_f annually in the EU27 region, depending on the assumptions. Berggren et al. (2008) studied the economic potential for such co-firing in Poland, when the prices and resources of biomass are exogenously given. Their results suggest that all available woody biomass could be used for co-firing in the existing boilers. Thus, it is the amount of biomass that limits the production of bioenergy in Poland.

1.3. Outline

In this study, we examine the effects of hypothetical carbon emission prices on the use of wood for energy and materials in the European Union in the next few decades. The carbon price may be interpreted as the price for a unit of CO_2 emission allowance or as an emission based tax on fossil fuels. In particular, we assess the economic potential to substitute wood for coal or peat in the heat and power production sector. In addition, we study the impacts of increased use of woody biomass for energy on the forest industry as well as on wood prices. Our approach differs from earlier studies in that we model the allocation of wood between the energy sector and forest industry in Europe endogenously.

We focus on the use of wood based biomass in large scale energy production in heat and power plants. The largest changes in wood use are expected to take place in this category. Currently, heat and power production account for 23% of the total wood use in the EU27 region. Other wood uses in the EU27 countries include material processing with a 58% share and small scale household energy production with a 19% share (IEA; FAOSTAT).

In the analysis, we use a simplified version of the EUFASOM model (Schneider et al., 2008), which is a dynamic partial equilibrium model for the forest sector. The reader will be introduced with the model in Section 2. Section 3 elaborates the data. The results are presented in Section 4. Section 5 concludes.

2. Method

The European Forest and Agricultural Sector Optimization Model (EUFASOM) has many common features with the FASOM model for the US forest and agricultural sectors (Adams et al., 1996; for recent applications, see, for example, Alig et al., 2010). In a previous study, a static version of EUFASOM has been used to estimate the economic potentials of wetland preservation (Schleupner and Schneider, 2010). In the model version developed for this analysis, the agricultural sector and land management are kept exogenous. Forest production activities are approximated by roundwood supply functions, which depend on price and forest growth. We enhance the model by introducing a richer set of forest industry production technologies and by adding wood and coal based heat and power production options, which compete for wood with the forest industry. We also introduce capacity dynamics for heat and power plants and the forest industry.

Schneider et al. (2008) provide a more detailed technical description of the principal mathematical structure of the EUFASOM model. Below, we give a brief and rather general introduction to the version applied and elaborate the issues that are either important for this study or differ from the original version. Similar to other spatial equilibrium models, EUFASOM is based on Samuelson's (1952) spatial price equilibrium principles. The operation of the economy is simulated by maximizing a social welfare function, which is the sum over regions and commodities of consumers' and producers' surpluses less interregional transportation costs, subject to market clearance, technological, and other constraints. An important difference between EUFASOM and some other forest sector models, such as Global Forest Products Model (GFPM, Buongiorno et al., 2003) and EFI-GTM (Kallio et al., 2004), is the assumed time horizon of the agents. In EUFASOM, the agents have perfect foresight, meaning that they consider all future costs and revenues resulting from their current decisions, while in an imperfect foresight model agents focus on the current period or on a limited number of future periods.

The social welfare maximization problem is

$$\underset{X_{tik},Y_{til},I_{tif},E_{tijk}}{\text{Max}} W=\sum_{t=0}^{T}\beta^{t}\cdot\left[\sum_{ik}\int_{0}^{X_{tik}}q_{tik}^{-1}(X)dX-\sum_{il}\int_{0}^{Y_{til}}c_{til}(Y)dY-\sum_{if}r_{tif}\cdot I_{tif}-\sum_{ijk}d_{tijk}\cdot E_{tijk}\right]$$
$$+\frac{\beta^{(T+1)}}{1-\beta}\cdot\left[\sum_{ik}\int_{0}^{X_{Tik}}q_{Tik}^{-1}(X)dX-\sum_{il}\int_{0}^{Y_{Til}}c_{Til}(Y)dY-\sum_{if}r_{Tif}\cdot I_{Tif}-\sum_{ijk}d_{Tijk}\cdot E_{Tijk}\right] \tag{1}$$

subject to

$$X_{tik}+\sum_{j}E_{tijk}\le\sum_{l}a_{tilk}\cdot Y_{til}+\sum_{j}E_{tjik} \qquad \forall t,i,k \tag{2}$$

$$Y_{tif}\le K_{tif} \qquad \forall t,i,f \tag{3}$$

$$K_{(t+1)if}\le(1-\delta)\cdot K_{tif}+I_{tif} \qquad \forall t,i,f \tag{4}$$

$$G_{(t+1)i}=(1+g_i)G_{ti}-\sum_{h}Y_{tih}/\nu \qquad \forall t,i \tag{5}$$

$$\sum_{h}Y_{tih}\le\nu\cdot g_i\cdot G_{ti} \qquad \forall t,i \tag{6}$$

$$Y_{tin}\le\sum_{k}\theta_{tkn}\cdot X_{tik} \qquad \forall t,i,n \tag{7}$$

$$Y_{tiw}\le\sum_{h}\lambda_{hw}\cdot Y_{tih} \qquad \forall t,i,w \tag{8}$$

$$K_{(t=0)if}=K_{if}^{0} \qquad \forall i,f \tag{9a}$$

$$G_{(t=0)i}=G_{i}^{0} \qquad \forall i \tag{9b}$$

$$E_{tijk},I_{tif},K_{tif},X_{tik},Y_{til},G_{ti}\ge0 \qquad \forall(\cdot) \tag{10}$$

where *t* refers to time, *i* and *j* to region, *k* to product, and *l* to production alternative. Among the production alternatives, *f* refers specifically to activities producing forest industry products or heat and power, *h* to roundwood harvest activities, *w* to activities related to collecting of forest chips, and *n* to activities recovering waste wood and waste paper. Among the variables, W denotes welfare, X_{tik} is domestic consumption of final products, Y_{til} is level of activity, I_{tif} denotes capacity investments, E_{tijk} is interregional trade, K_{tif} is capacity, and G_{ti} is the volume of growing stock of forests. Among the parameters, β is discount factor, r_{tif} is investment cost, d_{tijk} is transportation cost between regions, a_{tilk} is input–output coefficient, δ is capital depreciation rate, and g_i is growth rate of the forest stock, ν is the share of roundwood under bark obtained from roundwood harvest activities, θ_{tkn} is the share of end consumption of product *k* that can be recovered for reuse by activity *n*, and λ_{hw} is the share of forest chips in roundwood harvests that can be collected by activity *w*. Finally, $q^{-1}(X)$ is the inverse demand function, and $c(Y)$ is the marginal cost function.

Eq. (1) is the objective function, which maximizes the discounted sum of consumers' and producers' surpluses less transportation and investment costs. The discount factor β equals $\frac{1}{(1+\tau)^5}$, with τ being the annual discount rate. The first integral is the area underneath the inverse