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The trade-off between food production and greenhouse gas mitigation in Norwegian agriculture

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ABSTRACT

Agriculture in Norway makes a significant contribution to the country's emissions of greenhouse gases (GHG). Although it accounts for only 0.3 percent of the country's gross domestic product, it is estimated to account for roughly 9 percent of total GHG emissions. Norwegian agriculture is dominated by livestock production; ruminants (cattle and sheep) are particularly important. There are opportunities for GHG mitigation under existing technology, both through changes in agricultural practices and through sequestration activities, particularly agro-forestry. Using a detailed economic model based on representative farms we assess the impact of a targeted reduction of 30 percent in GHG emissions on agricultural activity—the continuation of which is a key policy objective in Norway. Implications of mitigation are examined both for a representative dairy farm and for the sector as a whole.

The imposition of a CO_2 tax on agricultural activity would result in a reduction of agricultural production in Norway, particularly for GHG-intensive commodities such as beef and sheepmeat. Focusing on a representative dairy farm we conclude that measures that facilitate higher intensity and yields in Norwegian milk production would make it possible to cut emissions per unit of milk. For the agricultural sector as a whole, there would be an extensification of production and emissions per hectare would decline. In contrast, if farmers were rewarded for carbon sequestration activities (specifically agro-forestry) this would lead to intensification, as more inputs are applied to the land remaining in agriculture. Emissions per unit of agricultural land would increase but would decline per unit of output. For a given targeted reduction in agricultural GHG emissions, overall production can be kept highest under an intensification strategy.

Although the numerical results are specific to the Norwegian setting, they are illustrative of issues facing other countries whose agriculture is dominated by ruminants. They are also supportive of arguments made by others that if global agriculture is to meet the needs of an expanding world population while simultaneously contributing to mitigation of GHG emissions, changes in the structure of production and intensification will be required.

1. Introduction

Norway has been a strong supporter of initiatives to reduce greenhouse gas (GHG) emissions, for example, by proposing a commitment to a 30 percent reduction from base period levels prior to the UN climate change conference in Copenhagen in November 2009. Unlike many other countries Norway derives much of its domestic energy from renewable sources (hydroelectricity). Manufacturing industries, mining and oil and gas extraction, which together account for over 40 percent of gross domestic product (GDP) contribute the largest share of Norway's GHG emissions (roughly 50 percent). However, agriculture which accounts for only 0.3 percent of GDP, contributes roughly 9 percent (Statistics Norway, 2013). Methane produced by farm animals, particularly cattle and sheep, which are the backbone of farming in the country, makes up nearly 60 percent of the emissions from agriculture.

In recent years various analytical approaches have been used to examine the effects of agricultural production and policies on GHG emissions (Smith et al., 2007). Some analysts have constructed models that focus on production decisions and practices at the farm level (e.g., Gibbons et al., 2006; Oleson et al., 2006; Weiske et al., 2006), others have taken a sectoral approach (e.g., McCarl and Schneider, 2001; Hynes et al., 2013). In focusing on Norway in this paper we follow the approach adopted by McCarl and Schneider (2001) by using a partial equilibrium model of the agricultural sector constructed on the basis of representative farms. We use the

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model to assess the impact of a 30 percent cut in agricultural GHG emissions on the level of agricultural production—the maintenance of which is a key agricultural policy objective in Norway. Two alternative scenarios are compared. The first involves a carbon tax on emissions from agricultural activity, while the second assumes that in addition to the tax farmers are paid for non-food sequestration activities on agricultural land (agro-forestry).

To gain knowledge about mitigation options, abatement costs, and industry impacts, the Norwegian authorities have initiated a series of studies on the reduction of GHG emissions from major sectors of the economy. For agriculture, proposals at the farm level relate to biogas, biochar, and the management of animal manure (LMD, 2009; KLIF, 2010a). Some options have been estimated to have marginal impacts on agricultural emissions (e.g., fertilization management; manure management), others involve high costs (e.g., replacing fossil fuel with bioenergy feed stocks), or are difficult to assess without further analysis (e.g. biogas; biochar) (KLIF, 2010a). In this paper we do not seek to provide a comprehensive abatement cost analysis for Norwegian agriculture that covers all technological options (e.g., Moran et al., 2011). Rather we focus on what changes in existing input use and the composition of output would be possible in order to reduce agricultural emissions in line with Norway's proposed reduction of 30 percent in its national GHG emissions. We start with a farm level analysis by examining the possibilities for increasing emissions efficiency (reductions in emissions per unit of output) for a representative dairy farm. We then extend our analysis to the sector level in order to investigate the potential to shift production from high to low emission products.

Agriculture is unusual because in addition to having the potential to reduce its emissions through changes in production technology and the level and composition of output, it can also contribute to GHG reduction targets by engaging in activities that promote carbon sequestration—the accumulation of atmospheric carbon in soils or plant material (e.g., through the production of woody biomass). We examine the implications of offering a payment to farmers for planting trees on land currently used for agricultural production (agro-forestry). Norway has agri-environmental programs that provide incentive payments to farmers to promote a range of environmental objectives and these programs could be adapted to promote sequestration activities (Huso, 2010).

Norwegian agriculture is currently highly protected from international competition. A key policy objective is to keep agricultural activity as high as possible within the constraints imposed by international trade agreements in the World Trade Organization (Blandford et al., 2010). We incorporate this objective into our analysis. Consequently we do not aim to identify a welfare maximizing solution for GHG mitigation in Norwegian agriculture, since that would likely imply a politically unacceptable reduction in agricultural activity. Rather our focus is on changes in existing production structure and practices that could be employed to meet Norway's stated GHG reduction target within the broad outlines of current agricultural policies. Such constrained optimization is likely to be the sort of approach to GHG mitigation adopted by many countries that have traditionally provided financial support for their agricultural sectors.

2. The model and the representation of GHG emissions

Our sectoral model (Jordmod) has been used previously to address a number of policy issues including the provision of public goods in Norwegian agriculture (Brunstad et al., 1999, 2005) and the effects of trade liberalization (Blandford et al., 2010). A technical description of the model is given in Brunstad et al. (1995); the latest version is documented in Mittenzwei and Gaasland (2008).[1] We provide a brief overview of the model, with an emphasis on adaptation to reflect GHG emissions. Further details are provided in Appendix A.

Jordmod is a price-endogenous, partial equilibrium model of the type described by McCarl and Spreen (1980). For given technology and demand functions, domestic market clearing prices and quantities are computed. Prices of goods produced outside the agricultural sector or abroad are taken as given, and domestic and imported products are assumed to be perfect substitutes. Full mobility of labour and capital is assumed. Domestic production takes place on "model farms" with fixed input and output coefficients.[2] The model farms span 11 representative farm types (e.g., combined milk and beef, grains, etc.), distributed over 32 production regions (with varying yields and limited supply of different grades of land), supplying 22 outputs (e.g., wheat, potatoes, cow's milk, eggs etc.) by means of 12 intermediate products (e.g., different grades of concentrated feed and roughage) and 25 other production factors (e.g., land, capital, labor, seeds, pesticides, etc.).[3] The produce from the model farms goes through processing plants before being offered on the market. Table A1 in Appendix A compares main results of the optimization for the given conditions and policy instruments in the base year 2004. As can be seen, both production and use of land categories are close to actual figures. This also applies to agricultural support.

Functions and coefficients have been attached to activities and production factors in Jordmod to reflect GHG emissions, based on the Intergovernmental Panel Climate Change (IPCC, 1995) methodology, adapted to Norwegian conditions and practices.[4] Details are given in Gaasland and Glomsrød (2010). For milk cows, emissions from enteric fermentation are represented as a function of the amount and mixture of feed, while for all other animals they are reflected by an animal-specific constant parameter per head. The amount of manure, which leads to emissions of methane and nitrous oxide from manure management and nitrous oxide from the use of manure as fertilizer, is modeled as a function of fodder intake for dairy cows and as an animal-specific constant for other animals. For manure management, animal-specific emission parameters depend on the manure management system. Constant parameters per unit of nitrogen, which differ between the use of manure and synthetic fertilizer, represent emissions of nitrous oxide from the use of fertilizer. Emissions from land use relate to carbon dioxide that is released from tilled mineral soil (estimated to be 1000 kg per hectare per year).

[1] The model is designed to perform policy analysis, and has as such been used by the Norwegian Ministry of Finance and the Norwegian Ministry of Agriculture.

[2] Although inputs cannot substitute for each other at the farm level due to the fixed coefficient assumption, there are substitution possibilities at the sector level. For example, beef can be produced using different technologies (represented by model farms), both extensive and intensive production systems, and in combination with milk. Thus, in line with the general Leontief model in which more than one activity can be used to produce each good, the isoquant for each product is piecewise linear. Also, production can take place on small farms or larger and more productive farms. Consequently, economies of scale are reflected in the model.

[3] The model farms are optimized (in a separate module) for given prices, subsidy and tax rates, subject to functions for production technology (e.g., output and input coefficients per ha or per animal), and biological or natural restrictions. To increase the scope for substitution, model farms are constructed for different sets of relative prices (depending on specific scenarios). The data for the model farms are based on extensive farm surveys carried out by the Norwegian Agricultural Economics Research Institute.

[4] Values are for 100-year time horizon global warming potential relative to $CO_2$from the IPCC second assessment report (IPCC, 1995). These values are those currently used by the Norwegian authorities in preparing GHG inventory reports for the United Nations. Although values have been revised in the fourth assessment report (IPCC, 2007) we chose not to use these in order to maintain consistency with Norway's reporting procedures. Changing the coefficients would affect our numerical results but not the qualitative conclusions.