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TRADE-OFF BETWEEN FOOD PRODUCTION AND GREENHOUSE GAS MITIGATION IN NORWEGIAN AGRICULTURE

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

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Abstract:
Norwegian agriculture makes a disproportionate contribution to the country's emissions of greenhouse gases (GHG) relative to its contribution to gross domestic product (GDP) – a picture that is repeated globally. Using a detailed economic model we examine what impacts an assumed 30 per cent cut in GHG emissions from agriculture may have on food production. We find that a CO_2 *tax on agricultural activity would result in a reduction of agricultural production, particularly of GHG-intensive commodities such as beef and sheepmeat. The use of feed and fertilizer would fall. There would be an extensification of production and emissions per hectare would decline. In contrast, if farmers are rewarded for carbon sequestration through agro-forestry, this would lead to intensification. More inputs would be applied to land that remained in agriculture and emissions per unit of agricultural land would increase. Although the numerical results are specific to the Norwegian setting, they are illustrative of global issues. If agriculture is to meet the food needs of an expanding world population while simultaneously contributing to mitigation of GHG emissions, this will require the intensification of production - higher output per unit of land with higher emissions per unit of land area, but with lower emissions per unit of agricultural production.*

1. Introduction

Globally, agriculture makes a disproportionate contribution to anthropogenic emissions of greenhouse gases (GHG) to the atmosphere. Although agriculture accounts for only 6% of global gross domestic product, the Intergovernmental Panel on Climate Change has estimated that it is responsible for roughly 14% of total GHG emissions (IPCC, 2007). That figure does not include any additional contribution of converting land from forest to agricultural uses. The world faces the prospect of increasing pressure on agriculture due to population and income growth and the resulting higher demand for food and fibre. The United Nations projects that by 2050 the world's population will have risen to over 9 billion, compared to roughly 7 billion currently, an increase of almost one third. Analysts at the Food and Agriculture Organization (FAO) estimate that in order to maintain the current global food availability of roughly 3 000 kcal per capita per day by 2050 an additional billion tonnes of cereals and 200 million tonnes of meat would be needed compared to supplies in 2005-07 (Bruinsma, 2009). The prospect of the need to increase food and fibre production substantially, while simultaneously meeting a climate change objective of limiting GHG emissions poses a considerable challenge.

Although Norway is a small country with a population of 5 million on the northern rim of Europe, its situation with respect to emissions from agriculture is proportionally worse than that at the global level. Agriculture accounts for 0.3% of Norway's gross domestic product (GDP), but is estimated to contribute around 8% of Norway's emissions of greenhouse gases (GHG). Methane produced by farm animals, particularly cattle and sheep, which are the backbone of farming in the country, make up roughly 80% of total GHG emissions from agriculture. The production of milk and beef alone is estimated to account for over 60%. Norway has been a strong supporter of initiatives to reduce global GHG emissions, for example, by proposing a 30 per cent reduction from base period levels in the run-up to the UN climate change conference in Copenhagen in November 2009.

On this background the authorities initiated a set of studies directed to the reduction of GHG emissions from important production sectors. For the agricultural sector it was written white papers, for example KLIF (2010a) and LMD (2009). Here it was proposed emission actions at the farm level, related to biogas, biochar, and the management of animal manure. However, in KLIF (2010a) these actions have been estimated to have marginally impacts on agricultural emissions (e.g., fertilization management; manure management), to have high costs (e.g., replacing fossil fuel with bioenergy feed stocks), or they requires no sector model to be studied (e.g. biogas; biochar). Unlike the white papers, our analysis is based on a drastic reduction in GHG emissions from the agricultural sector in line with the national goal, i.e. 30 per cent.

Agriculture is unusual since in addition to having the potential to reduce its own emissions through changes in production technology and the level and composition of output, it also can contribute to meeting its own or national emission 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). In this article we examine the implications of imposing an explicit or implicit emissions tax on Norwegian agriculture, and contrast this to combining such a tax with a reward for sequestration activities (our focus is on agro-forestry). In assessing the two options we take into account the fact that Norwegian agriculture is currently highly protected from international competition and the political aim is to keep agricultural activity as high as possible within the constraints imposed by international trade agreements in the World Trade Organization.

2. Empirical analysis of abatement strategies

Our empirical analysis focuses on the trade-off between food production and GHG emission cut related to use of agricultural land. The analysis takes the perspective of a small country whose agriculture is currently protected and whose political aim is to keep agricultural activity as high as possible within an assumed constraint on GHG emissions. In that setting, abatement costs can be interpreted as production foregone (more generally, they can be assessed by considering changes in economic welfare). Since adaptation serves to mitigate abatement costs, the analysis allows for changes in farm level practices and a shift from high to low emission outputs.

The tool that we use as the basis for our analysis is a partial equilibrium model for the Norwegian agricultural sector: Jordmod. Further details on the model are given below. Using the current agricultural support system as a point of departure, we introduce a tax on net GHG emissions from agriculture into the model. The size of the tax is estimated as that needed to achieve a reduction of roughly 30 percent in emissions from Norwegian agriculture. A 30 percent reduction in national emissions was proposed by Norway in the run-up to the 2009 U.N. Climate Change Conference in Copenhagen. As stressed in the introduction, this does not accord with the current national policy. Our analysis must be viewed as a computational exercise that we perform in order to study abatement costs, agricultural sector impacts, and economic welfare effects of major strategies to reduce GHG emissions.

Based on the change in practices and production composition that follows from this tax, we scale the aggregate level of production up or down to meet the 30 per cent emission target. The Norwegian market for agricultural products is more or less isolated from foreign competition and prices are highly distorted through production subsidies, hence the resulting solutions are not economically efficient, but rather reflect the approach of existing agricultural policies.

We distinguish between two alternative abatement strategies that affect adaptation and production in different ways. The first strategy involves a carbon tax on net emissions from agricultural activity alone, while the second assumes that sequestration activities on agricultural land are rewarded even if such sequestration is decoupled from food production (e.g., land previously devoted to agriculture is converted to forestry). In contrast to the first strategy, non-food sequestration incentives have the tendency to increase productivity and agricultural emissions per land unit in order to release farm land for sequestration purposes. Even through our analysis is confined to a small country, by using a closed economy perspective our analysis suggests more general conclusions. In particular, it suggests that combining targets for providing increasing food production to meet the needs of a growing population while simultaneously reducing GHG emissions may imply the need to intensify production on scarce land even this results in higher emissions per unit of land devoted to agriculture.

3. The empirical model

Jordmod has been used to analyse the provision of public goods in Norwegian agriculture (Brunstad *et al*. 1999 and 2005) and the effect of trade liberalization (Blandford *et al*. 2010). A technical description of the model is given in Brunstad *et al*. (1995); the latest version of the model is documented in Mittenzwei and Gaasland (2008).[1] We here provide a brief overview of the model, with an emphasis on the treatment of GHG emissions.

Jordmod is a price-endogenous, partial equilibrium model of the type described in 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

[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.

taken as given, and domestic and imported products are assumed to be perfect substitutes. As the model assumes full mobility of labour and capital, it should be interpreted as a long run model. 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), distributed over 32 production regions (with varying yields and limited supply of different grades of land), supplying 22 outputs (e.g., wheat; potatoes; cow milk; eggs) by means of 12 intermediate products (e.g., different grades of concentrated feed and roughage) and 25 other production factors (e.g., land, capital, labour, seeds, pesticides)[3]. The produce from the model farms go through processing plants before they are offered on the market. In order to illustrate the potential implications of mitigation policies at the farm level, we examine in section 4 the results of analysis for a representative Norwegian dairy farm – one of the key farm types that is included in Jordmod.

The model's base year is 2004. In most directions Norwegian agriculture has not changed much the last decade, so this year is representative also for the current situation. However, there are exceptions. First, consumption and production of chicken has markedly increased. The same applies for the intensity in milk production.

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) methodology, adapted to Norwegian conditions and practices. 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 it is given 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 modelled as a function of fodder intake for milk cows and as an animal-specific constant for other animals. For manure management, the animal-specific emission

[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.

parameters depend on the manure management system. Constant parameters per unit of nitrogen, which differ between the use of manure and synthetic fertilizer, represent emission of nitrous oxide from the use of fertilizer. Carbon dioxide released from the use of fossil fuel in agriculture (which amounts to 9 per cent of estimated agricultural emissions) is not included in the model. The emissions of all substances are translated into carbon dioxide equivalents.

GHG policy instruments can be specified in the model either in the form of a tax on emissions or as a cap. In the latter case, the shadow price attached to the cap can be interpreted as the implicit tax, or the required tax to ensure that the cap is binding. The estimated tax of 300 NOK per ton of CO_2 used in our analysis was derived by imposing a 30 per cent cap on emissions in the model. The model allows for several responses to such a tax: activities with high emissions (e.g., ruminants) may decline to the benefit of those with lower emissions (e.g., monogastric animals); the intensity of the use of fertilizer may decrease (i.e., land may substitute for fertilizer); more of the land may be permanently covered with grass and not ploughed (use of no-till); and the intensity of feeding of milk cows may change.

GHG emissions, distributed by sources and gases for the model's base year of 2004, are given in Table 1. Methane from enteric fermentation accounts for 41 per cent of total emissions, while manure management makes up 24 per cent. Use of synthetic fertilizer, carbon loss from soil, and use of fossil fuel each add up to about 10 per cent.

Table 1: GHG emissions in CO_2 equivalents (1,000 tons) distributed by sources and gases (2004). Global warming potential (GWP) values: CH_4 = 21, N_20 = 310, and CO_2 = 1.

Source	**Methane** (CH_4)	**Nitrous oxide** (N_2O)	**Carbon dioxide** (CO_2)	**Total**	*(share)*
Enteric fermentation	1,843			1,843	41 %
Manure management	689	420		1,109	24 %
Fertilizer, manure		231		231	5 %
Fertilizer, synthetic		504		504	11 %
Nitrogen runoff		69		69	2 %
Land, net carbon loss			375	375	8 %
Fossil fuel			411	411	9 %
Total	2,532	1,224	786	4,542	
(share)	56 %	27 %	17 %		

Table 2 shows estimates of emission for representative farming activities in Norway that help to illuminate the potential for mitigation by changing the mix of outputs.[4] Emissions associated with the production of beef and sheepmeat are by far the highest, both per kg of output and in terms of output valued at world market prices. White meat and eggs are in the middle range per kg, and at the low end in value terms. Note that emissions relating to milk production are relatively low, especially per kg of milk. Emissions are by far the lowest for vegetables, here represented by potatoes. Measured per land unit (ha), emissions are lowest for grains and potatoes, while they are in the range of 3,800-4,000 kg per ha for most other types of activities.

Table 2: GHG emissions (CO_2 equivalents in kg) for representative farming activities in Norway*

Farm types	Per kg	Per NOK**	Per ha
Extensive beef	27.28	2.10	3,829
Sheep	19.69	0.98	3,982
Pigs	4.42	0.37	3,948
Poultry	3.00	0.33	4,278
Eggs	1.85	0,19	2,194
Combined milk and beef ***	0.66	0.60	3,852
Grain	0.38	0.50	1,661
Potato	0.12	0.05	1,581

* More details are given in footnote 4.
**Production measured at world market prices (NOK = Norwegian krone. At recent exchange rates €1 = 7.5NOK)
***Per kg of milk. Emissions from beef production are deducted (assuming 20 kg CO_2 equivalent per kg of beef).

[4] Included are emissions at the farm level from enteric fermentation, manure management, use of fertilizer, nitrogen runoff, and land use. For purchased inputs, only emissions related to the production of purchased grain feed are included (CO_2 emissions of 0.41 kg per unit of purchased grain are used, computed from an average barley yield of 3,670 feed units per ha using 84 kg N fertilizer per ha). The estimated GHG emission for each farm activity is divided by the agricultural produce measured in quantity (column 1), value (column 2) and land use (column 3).

4. Farm level adaptation – dairy farm example

As noted earlier, Norwegian milk farms are relatively small (on average about 25 milk cows) and the cows are not fed intensively. In this section we examine a representative dairy farm in the base year 2004. As can be seen from column 1 in Table 3, the yield per cow was on average 5,900 kilo (measured as delivery to dairy industry; total milk yield per cow was 6,469 kilo), and the share of grass in fodder intake was 63 per cent. The small scale bias has been promoted by a regressive support system (subsidies per cow and per kg decreases with scale) combined with regulations that restrict flexibility in changing farm size, e.g., land property regulations. Total milk production is restricted by a system of tradable quotas within regions. Since the milk quota price elevates costs in milk production, it also affects the optimal intensity of production at the farm level.

At the farm level, enteric fermentation accounts for 55 per cent of the emissions in milk production. Since emissions per kilo of milk decreases with the ratio of concentrated feed (Volden and Nes, 2007), one option is to facilitate higher intensity and yields in Norwegian milk production, e.g., by easing regulations that impair the farmers flexibility in use of inputs.

Column 2 of Table 3 shows that when the milk farmer is free to adjust the yield level, milk production per cow increases by 18 per cent while the share of grass fodder decreases from 63 to 60 per cent.[5] Both of these factors contribute to a reduction in emissions per unit of output. Measured per NOK produced, emissions are reduced by nearly 7 per cent and by 4 per cent per hectare.

In the next simulation, reported in Column 3, the CO_2 tax of NOK 300 per ton is imposed. Simultaneously, we raise the price of purchased grain feed in line with the tax (i.e., feed from grass and grain is subject to the same CO_2 tax) and, to compensate for higher costs, we also raise product prices (milk and beef). We see that the CO_2 tax only has a minor impact on farm level adaptation; yields per cow increase by roughly 1 per cent with a slightly higher grass share in feeding. The intensity in the use of N-fertilizer is decreased by 8 per cent. Emissions per NOK and per hectare are reduced by about 2 per cent. Even if the impacts are low, the tax works as expected in the direction of lower emissions per NOK and per hectare.

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[5] Since the base year 2004, yield per cow has in fact increased by about 10 per cent, while the share of grass in fodder intake has decreased to about 58 per cent. Consequently, some of the potential for lower emission per unit of milk produced has already been realised.

The last column shows adaptation when sequestration is rewarded. Sequestration is represented by afforestation of agricultural land which is assumed to bind a long run average of 10,000 kg of CO_2 per hectare per year.[6] The NOK 300 tax per ton of net emissions results in a payment of NOK 3,000 per hectare. For simplicity we assume normal profit in the forest activity such that the CO_2 sequestration payments eventually will appear in the land price that also confronts food producers. Consequently, the land price in both milk and feed grain production is assumed to rise by NOK 3,000 per hectare.

In this case production is intensified; i.e., both production and emissions are increased per hectare. The increase in land price disfavors, in particular, low yielding land (high tax per produced feed unit). Marginal pasture land is therefore taken out of production (afforested), and relative more of the livestock feed is composed of grain. Note also that the use of N-fertilizer per ha has increased significantly.

[6] The forest sequestration coefficient is a rough estimate that we use to illustrate the importance of sequestration options on the opportunity cost of land. According to the Norwegian Climate and pollution agency (KLIF, 2010b), spruce has the potential to bind about 11,000 kg CO_2 per hectare per year (as an average over 70 years).

Table 3: Farm level adaptation – dairy farm example

	Base Solution	Higher yield	Higher yield, and CO_2 tax	Higher Yield, CO_2 tax, and sequestration incentives
Production				
Milk (tons)	147.5	173.7	176.0	175.7
Milk (NOK at world market prices)	295.0	347.4	352.0	351.5
Beef (tons)	6.3	6.3	6.3	6.3
Beef (NOK at world market prices)	81.9	81.9	81.8	81.5
Land use at the farm (ha)	38.8	41.5	43.0	33.6
Mowed grass, tillable	25.3	27.0	28.3	29.8
Pasture, no-tillable	0.0	0.0	0.0	3.8
Pasture, infield	13	14	15	0
Land use purchased grain fodder (ha)	20.2	23.3	23.2	25.0
Total land use (ha)	59.1	64.7	66.2	58.6
Yield (feed units per ha)				
Mowed grass, tillable	3,978	3,980	3,864	4,090
Pasture, not-tillable	0	0	0	3,424
Pasture, infield	2,239	2,239	2,239	0
N-fertilizer (kg per ha)	157	157	144	226
Animals (number)	97	97	97	97
Dairy cows	25	25	25	25
Other	72	72	72	72
Output and input per dairy cow				
Milk production (kg)	5,900	6,949	7,041	7,030
Feed units (FEm)	4,843	5,642	5,734	5,721
Gross energy (MJ/cow/day)	297	321	323	325
Share of grass fodder	63 %	60 %	61 %	56 %
Emissions (tons CO_2 equivalents)	228	239	237	242
CH_4	150	154	154	153
N_2O	47	50	48	51
CO_2	0	0	0	0
Grain fodder (computed)	30	35	35	38
Emissions per ha (kg CO_2 equivalents)	3,852	3,693	3,581	4,127
Emissions per NOK (kg CO_2 equivalents)	0.60	0.56	0.55	0.56

5. Sector level adaptation – model simulations

A GHG tax has differential impacts on profitability between farm systems. As emphasized in Table 2, ruminants like cattle and sheep cause high emissions, both relative to output and the use of farm land, while emissions are moderate for milk and relatively low for white meat, eggs, grain and vegetables. We have also seen that only a minor part of the farm system differences in emissions can be mitigated by farm level adaptations, e.g., by changing practices in livestock feeding or use of fertilizer. Consequently, in order to achieve a substantial abatement in agricultural emissions while maintaining aggregate food production, it seems necessary to supplement farm with sector level adaptations; i.e., by switching the structure of production from high to low emission food products.

The model simulations in Table 4 allow for such adaptations. As in the previous section we use the current agricultural support system as a point of departure and a NOK 300 tax on GHG net emissions from agriculture. Since the domestic markets for agricultural products are closed by WTO bound tariffs that in general entail import costs far above domestic market prices, the carbon tax will, depending on the prevailing supply and demand conditions, be reflected in consumers' and producers' prices. Due to climatic conditions, some grain is imported. In the simulation we keep imports of grain used for fodder at the current level, which constitutes about 15 per cent of domestic demand. In this way we exclude the possibility that farms will expand activity based on imported feed not subject to the GHG tax (i.e., potential carbon leakage). Consequently, the GHG tax is reflected in the price of both grass and grain fodder. Finally, we require that the WTO Uruguay agreement is satisfied with respect to the use of production support and export subsidies.

Two alternative simulations are provided. In the first simulation, we assume that the GHG tax is only applied to net emissions from agricultural activity. In the second simulation we assume that sequestration on agricultural land also is rewarded. As explained in section 4, we assume that sequestration is achieved through afforestation which is assumed to bind a long run average of 10,000 kg CO_2 per hectare per year so that the NOK 300 tax per ton of net emissions results in a NOK 3,000 payment per hectare for afforested land. For simplicity we assume normal profit in the forest activity, such that the CO_2 sequestration payments are eventually reflected in the price of land that remains in agriculture.

Table 4. Sector level adaptation – model simulations

		Carbon tax	
	Base solution	No forest sequestration incentives	Forest sequestration incentives
Production	100	77	87
Cow milk	100	82	95
Other ruminants	100	66	51
White meat and eggs	100	83	97
Grains and potatoes	100	74	92
Farm land	100	74	66
Intensity			
Nitrogen per ha	100	95	115
Yield per dairy cow	100	119	120
Share of grass fodder per dairy cow	100	96	92
Emissions from agricultural activity (CO_2 equivalents)	**100**	**70**	**70**
GHG per NOK produced (measured at world market prices)	100	91	80
GHG per hectare	100	96	105
Agricultural support	100	74	80
Economic welfare	100	119	116

Table 4 shows the main results compared to the base solution (indexed to 100). In the first case, with the carbon tax and no sequestration incentives, Column 2 of Table 4 shows that a 23 per cent reduction in agricultural production is required to achieve the 30 per cent GHG abatement target. Adaptation, both at farm and sector level, explains why production declines less than emissions. At the sector level the results show that ruminants like beef and sheep suffer a larger reduction than white meat and milk. The reduction for grain is mainly a result of lower agricultural activity that reduces the demand for grain-based fodder.

At the farm level the aggregate use of nitrogen fertilizer decreases by 5 per cent while the yield per milk cow increases by 19 per cent. The combined effect of farm and sector level adaptations is a 9 per cent decrease in emissions per produced unit and a 4 per cent reduction in emissions per hectare. While the 30 per cent emission abatement involves costs in terms of production forgone, gains are generated in the form of lower agricultural support and higher economic welfare. The welfare result is more or less of a consequence of lower support driven agricultural production (Harberger distortions).

The inclusion of forest sequestration incentives implies, as mentioned earlier, a NOK 3,000 per hectare increase in agricultural land prices, and this provides an additional channel for change in the relative profitability of farm systems. The results in Column 3 indicate that aggregate production in this case can be maintained at a higher level (87 per cent of the current level). More substantial adaptation makes this possible. The tendency for reduced production of beef and sheepmeat relative to white meat, milk and grain is strongly reinforced. Observe that in comparison to the preceding simulation more food is produced on less agricultural land and GHG emissions per hectare of land in agriculture are increased. In order to release land for sequestration activities (afforestation) the intensity of agricultural production has increased.[7] Farm level indicators of this tendency are that the use of N-fertilizer per unit of land has risen and that marginal farm land has been taken out of production (low yielding infield pasture). A sector level indicator is that farms characterized by large production per land unit (i.e., white meat, grain, and milk) expand relative to land intensive farms (i.e., cattle and sheep).

One observation that can be made from these results is that at the farm level there seems to be a positive correlation between high emissions per produced unit (high emissions intensity) and land intensity. In other words, food production based on cattle and sheep not only generates high emissions per produced unit, but also demands a lot of land that alternatively could be used for sequestration activities. Relatively less emissions and land use are attached to white meat, milk and grain.

6. Conclusion

In this paper we have assessed GHG emission abatement costs in the perspective of a small country whose agriculture is highly protected and whose political aim is to keep agricultural activity as high as possible within an assumed constraint on GHG emissions. The focus has been on the trade-off between high food production and lower GHG emissions from activity on farm land. Consequently, other policy objectives or public goods related to agricultural activity are not considered. We acknowledge that more intensive use of farm land and afforestation on agricultural land will have negative impacts on both the amenity value of the landscape and

[7] Note that an important contributor to this result is the closed nature of the Norwegian agricultural economy and the fact that the bulk of food demand has to be met from domestic production.

biodiversity. Trade-offs along that dimension will be an interesting topic for future work, e.g., following the approach of Brunstad et al. (2005).

An abatement strategy that involves a carbon tax on net emissions from agricultural activity alone works, as expected, in the direction of lower emissions per produced unit and per hectare. On the contrary, when non-food sequestration activities on agricultural land are rewarded (e.g., land previously devoted to agriculture is converted to forestry), there is a tendency to increase production intensity and agricultural emissions per land unit in order to release farm land for sequestration purposes.

While the first strategy implies extensification and the other intensification of farming, a common feature is that both strategies suggest reduced production of beef and sheep meat relative to white meat, milk, grain and, in particular, vegetables. In other words, food production based on cattle and sheep not only generates high emissions per produced unit, but also demands a lot of land that alternatively could be used for sequestration activities. A second common feature is that measures that facilitate higher intensity in milk production may serve as a cost efficient way to reduce emissions while keeping up milk production.

Even through our analysis is confined to a small country, by using a closed economy perspective our analysis suggests more general conclusions. In particular, it suggest that combining targets for providing increasing food production to meet the needs of a growing population while simultaneously reducing GHG emissions may imply the need to intensify production on scarce land even this results in higher emissions per unit of land devoted to agriculture.

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