Interaction between trade liberalization and climate change policy: an application to Norwegian agriculture

1. Introduction

Multinational negotiations relevant to agriculture are taking place in two separate arenas. In the United Nations (UN) climate change conferences, the most recent of which was held in Cancun, Mexico in November 2010, efforts are being made to reach an agreement on binding global commitments on future greenhouse gas (GHG) emissions. Although agriculture has been exempted so far from most national initiatives in this area, there are likely to be pressures to include the sector in future GHG tax or quota systems. Concurrently, efforts continue to conclude the Doha Round of trade negotiations through the World Trade Organization (WTO) where agriculture is at centre stage.

GHG emissions from agriculture are disproportionate to the size of the sector. Although agriculture accounts for roughly 6 per cent of global GDP, it generates close to 10-12 per cent of global GHG emissions (CIA, 2011; Wreford et al., 2010). Agriculture is, at the same time, a heavily subsidized sector in many developed countries. In the member countries of the Organization for Economic Co-operation and Development (OECD), total public support is equivalent to 30 per cent of the value of agricultural production.

Though negotiated separately, there are linkages between GHG and trade issues. GHG emissions have the characteristic of a negative externality that inflicts costs on society through the effects of climate change. In absence of appropriate taxes or regulations, GHG-intensive products are implicitly subsidized relative to less-intensive products, and this affects international trade. Farm support also affects GHG emissions since the profitability of different production systems changes. The mechanisms are many: at the farm level the intensity of the use of land can be affected (e.g., the amount of fertilizer applied; the amount of tillage); at the sector level incentives with respect to the choice of outputs are distorted (e.g., ruminants vs. monogastric animals; meat vs. vegetable products); and at the global level production tends to be shifted from regions with a natural advantage in agriculture to those that provide the highest support.

In this paper we explore strategies for complying with trade liberalization and GHG emission reduction commitments. Our 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 the constraints imposed by multinational agreements. We compare the implications of trade liberalization and a carbon tax, both of which affect agricultural output, as means of achieving a sector-specific emission reduction. We examine two different responses to the introduction of a price for carbon. One is to change the way agricultural commodities are produced, i.e., to use less polluting techniques, which we argue will require more land per unit of output. A second is to use agricultural land for carbon sequestration purposes (offsets), e.g., for perennial grasses of forestry. We show that when the offset option is introduced, production intensity tends to increase; such that emissions per unit of output also increase.

We use a model of Norwegian agriculture to demonstrate the impact of GHG and trade policy options. Norway has been a supporter of initiatives to reduce 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. At the same time, Norwegian agriculture is among the most heavily protected in the world. According to figures published by the OECD Secretariat the producer subsidy estimate for 2009 was 66 percent, the highest among the OECD member countries (OECD, 2010).

The basis for our analysis of the impact of alternative policies is elaborated using a simple model in Section 2. The detailed model of Norwegian agriculture that we use to derive empirical estimates is described briefly in Section 3. In Section 4, we use the model to derive estimates of the impact of alternative policies. The point of departure is the model's representation of current policy, which reflects the agricultural policy of a small, high support country with comparative disadvantage in agriculture. In the final section we summarize our conclusions.

2. A simplified exposition of the basis of our analysis

In the Section 4 we use a full scale model of Norwegian agriculture to explore the interaction between trade liberalization and climate change policy. As a background for that analysis, this section outlines the main mechanisms involved and explains the scenarios to be examined.

Let us consider a simple aggregate production function for agriculture of the form:

(1) $$Y = F(K, L),$$

where Y is production, L is land, and K is an aggregate of other inputs, for simplicity denoted as capital. The production function is assumed to be homothetic and well-behaved. In Figure 1, point 0 at the isoquant *Y'* represents the production level in a base solution (with current policies). It is assumed that the amount of land used in the base solution, $\overline{L}$, is equal to the maximum amount of land available for agricultural production.

The relation between production and agricultural GHG emissions, *AE*, is assumed to be given by:

(2) $$AE = AE(K,L) = e(\frac{K}{L})Y = e(\frac{K}{L})Y(K,L)\ .$$

For a given capital/land ratio, emissions are assumed to increase proportionally with production (the *production effect*). However, emissions are also assumed to be affected by the capital/land ratio. We assume that capital is the main source of emissions in agricultural production, i.e., for a given production level, emissions increase with the capital/land ratio (the *intensity effect*).

The curve AE^* in Figure 1 shows capital/land combinations that, for a given level of emissions ($\overline{\mathrm{E}}$), are consistent with these properties. We have drawn the emission curve AE^* as less steep than the isoquant *Y''* passing through point 2. The explanation for this is as follows: assume that we are at point 2, and the amount of land is increased. Y will then increase, and so will emissions (through the *production effect)*. In order to keep production unchanged (*Y''*) a decrease in capital is required. In order to keep emissions constant capital also has to be decreased. But because of the intensity effect, capital does not have to decrease as much in order to keep production unchanged.

Assume as a next step that climate policies allow for credits for carbon sequestration (carbon offsets) on land taken out of agricultural production. The sequestered amount of carbon, denoted S, is assumed to be given by:

(3) $$S = \lambda(\overline{L} - L)$$

where λ is the sequestration coefficient per hectare. When sequestration is deducted from emissions in agricultural production, we obtain a measure of net emissions, *NE*:

(4) $$NE = AE(K,L) - S(L) = e(\frac{K}{L})Y(K,L) - \lambda(\overline{L} - L).$$

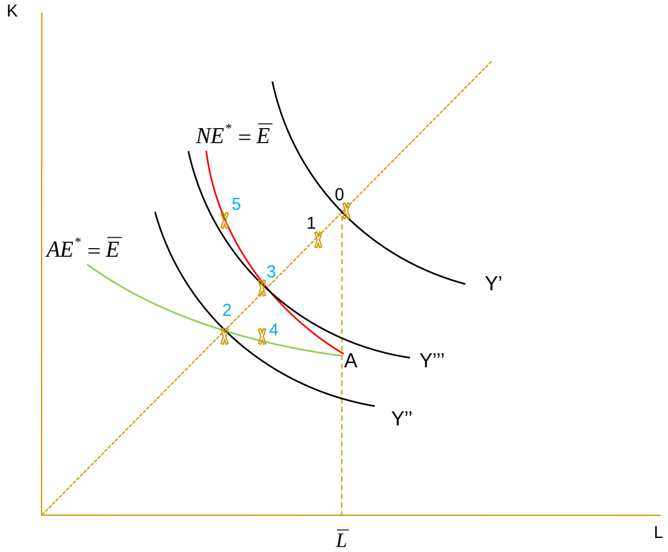
The net emission curve that corresponds to the AE^* curve is depicted by NE^*. We see that the two curves have a common point at *A*. Since $L = \overline{L}$ at this point, no agricultural land is devoted to carbon offsets, i.e., $AE = NE$. Furthermore, the NE^* curve is steeper than the AE^* curve since land used in agricultural production displaces carbon sequestration activities.[1] For a sufficiently high sequestration coefficient, λ, the NE^* curve will, as depicted in the figure, be steeper than the production isoquant Y’’’. Hence, when sequestration activities allow for a credit against the emissions generated by agricultural production, the transition to a more capital intensive (i.e., less land intensive) agriculture may well result.

Assume that $\overline{E}$ is an emission ceiling imposed on Norwegian agriculture. If the GHG account only includes emissions from agricultural production, the sector confronts the restriction $AE \leq \overline{E}$. Emissions are then confined to the curve $AE^* = \overline{E}$ in Figure 1. However, if carbon sequestration on land released from agricultural production is credited, the restriction becomes $NE \leq \overline{E}$, which corresponds to the curve $NE^* = \overline{E}$.

Based on this general framework, we define the scenarios for our empirical model. The base solution (Section 4.1), which serves as a reference point, corresponds to point 0 in Figure 1. Since the base solution is to the north-east of both point 2 and point 3, it yields emissions in excess of the target ($\overline{E}$). In addition, the base solution in terms of support and protection is not in compliance with an anticipated WTO Doha agreement.

[1] Compared to the AE^* curve, when carbon offset is an option (NE^* curve), more land in agricultural production requires a larger decrease in the use of capital in order to keep emissions at the same level.

Figur 1. Trade liberalization versus carbon tax



One strategy to try to reduce emissions in a highly protected agriculture is to reduce that protection and liberalize trade. In the simplified exposition in Figure 1, trade liberalization is mimicked by a reduction in output prices (i.e., unchanged input prices), for example due to reduction in import tariffs or production-related subsidies. Since the production function is homothetic, we then move down the straight line ray. As will be shown in Section 4.2, based on a comprehensive model implementation of the Doha proposal, trade liberalization implied by the draft agreement on agriculture will not have a major impact on Norwegian agricultural production and emissions. This is illustrated by point 1 in the figure, at which emissions remain far above the ceiling.

In Section 4.3 we examine the use of additional trade liberalization as a strategy, i.e., as a way of meeting the emission target $\overline{E}$. In the most dramatic case, which excludes credits for sequestration, we end up at point 2. Point 3 shows that production can be kept at a higher level, i.e., less trade liberalization is required, if carbon offsets are allowed. Since factor prices are assumed to be unchanged in the example shown in the figure, so is the capital/land ratio.

A more targeted way of reducing emissions is through the use of an explicit or implicit GHG tax. The relative prices of production factors will then change to the benefit of those with lower emissions, so that the target on emissions can be met at lower costs through substitution. Since capital is assumed to be the high emission factor in agriculture in the simple example in this section, land would replace capital when sequestration is excluded as an option, and this would bring us to point 4. However, as explained earlier, when carbon offsets can be used this may reverse factor intensity, i.e., move us towards point 5. Using the full scale model, the strength of these mechanisms is investigated in Section 4.4.

3. The empirical model of Norwegian agriculture and the representation of GHG emissions

The tool that we use to examine empirically the issues set out in the previous section is a partial equilibrium model for the Norwegian agricultural sector; Jordmod. The model has been used earlier to analyse the provision of public good by Norwegian agriculture (Brunstad et al. 1999 and 2005) and the effect of trade liberalization on the Norwegian agricultural sector (Blandford et al. 2010). A technical description of the model is given in Brunstad et al. (1995), while the latest version of the model is documented in Mittenzwei and Gaasland (2008). In the following we provide a brief overview of the model, with special 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 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

[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 (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 more productive farms. Consequently, there is an element of economies of scale in the model.

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.

Functions and coefficients have been attached to activities and production factors in the model to reflect GHG emissions, based on the Intergovernmental Panel Climate Change (IPCC) methodology, adapted to Norwegian conditions and practices. Details, including parameters, data sources and implementation, are given in Gaasland and Glomsrød (2010), but a short overview is presented below.

Table 1. Sources of GHG emissions in Norwegian agriculture: CO_2 equivalent in mill. kg. and percentage of total

Enteric fermentation	1,917 (35%)
Manure management	1,108 (20%)
Fertilizer, manure	233 (4%)
Fertilizer, syntetic	576 (11%)
Net emmision land use	1,530 (28%)
Other	69 (2%)
Total GHG emissions	*5,433 (100%)*

The sources and the actual numbers of GHG emissions from Norwegian agriculture are given in Table 1. All of these are incorporated into the model. For milk cows, emissions from enteric fermentation are expressed 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 through manure management, and nitrous oxide generated by 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 parameters depend on the system applied. Constant parameters per hectare, which differ between the use of manure and synthetic fertilizer, represent emissions of nitrous oxide from organic and inorganic

[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 are based on extensive farm surveys carried out by the Norwegian Agricultural Economics Research Institute.

fertilizers. Net emissions from land use relate to carbon dioxide that is assumed to be released from tilled land (2,000 kg per hectare per year) adjusted for the small amount assumed to be sequestered on no-till land (about 100 kg per hectare per year). The ‘other’ category in Table 1 includes indirect emissions related to deposition of ammonia and leaching and runoff of nitrogen. Carbon dioxide released by the use of fossil fuel in agricultural activity (which amounts to 8 per cent of the agricultural emissions) is not included in the model. Emissions of all substances are translated into carbon dioxide equivalents.

4. Model analysis

As indicated above our 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 the constraints imposed by multilateral agreements. The point of departure is existing policy, as generated by the model for the base year 2003. With respect to a potential new WTO trade agreement, we employ the Falconer proposal of December 2008 (WTO, 2008). No similar global climate policy proposal or commitment exists. However, prior to the Copenhagen climate conference, Norway proposed a reduction in economy-wide emissions of 30 per cent by 2020 (compared to the 1990 level). In our analysis we assume that agriculture has to reduce its GHG emissions by that percentage.

4.1 Current situation

The model’s representation of agricultural policy in the base year 2003 is reported in column 1 of Table 2. Since the production of agricultural commodities, as well as agricultural support, has been relatively stable over the last decade, the base year 2003 is representative of the Norwegian support regime. In what follows we emphasize current status with respect to trade liberalization and GHG emissions.

Norwegian agriculture, which accounts for less than one per cent of GDP and three per cent of domestic employment, is among the most heavily protected in the world (NILF, 2007).[4] As noted earlier, the OECD’s Producer Support Estimate (PSE) for Norway was 66 per cent in 2009, the highest among the Organization’s member countries (OECD, 2010). The total agricultural support generated by the model is NOK 20.1 billion (1 NOK ≈ 0.125 €), of

[4] In spite of climatic disadvantage, Norway is self-sufficient in the main temperate zone products, with the exception of grain. 10 per cent of the milk production is exported in the form of cheese, by means of export subsidies.

which NOK 11.8 billion is various forms of budget support and NOK 8.6 billion is market price support buttressed by import tariffs for major products in the range of 190-430 per cent.[5] Market price support and output subsidies constitute 60 per cent of the total support. (these numbers are not reported in Table 2.

The first column in Table 2 shows that Norway exceeds the proposed Doha commitment on the Total Aggregate Measurement of Support (TAMS) 102 per cent, Blue Box commitment by 111 per cent and the Overall Trade Distorting Support (OTDS) by 95 per cent. Consequently, Norway is far from free trade in agriculture, and the sector would apparently be severely affected by extensive trade liberalization.

Even through agriculture accounts for less than 1 per cent of Norway's GDP, it contributes 9 per cent of the country's total GHG emissions. Table 1 shows how these emissions are distributed across various sources. Enteric fermentation accounts for more than 1/3 of total agricultural emissions. This source is closely related to the number of ruminants (i.e., dairy cows, heifers, beef cows, sheep and goats), which are the basis of most agricultural production activity in Norway's rural areas. Net emissions from agricultural land are the second largest category. Intensive soil tilling contributes to high emissions from agricultural land. Almost 90 per cent of the land is regularly tilled, i.e., land with permanent cover is scarce. 20 per cent of the emissions come from manure management, which is also correlated with the number of animals, inclusive of pigs, poultry and hens. Roughly 15 per cent of total emissions are associated with the use of fertilizer (organic and inorganic). Intensive soil tilling and use of fertilizer are a ways to compensate for climatically-induced low yields and a short growing season. GHG taxes or regulations have so far not been imposed on Norwegian agriculture.

[5] By comparison, the actual producer subsidy estimate (PSE) reported by OECD for 2003 is NOK 21.7 billion, of which NOK 12.5 billion is budget support and NOK 9.2 billion is market price support.

Table 2. Trade liberalization versus carbon tax – Model results

	Base solution	**Doha solution**	**Further trade liberalization**		**Carbon tax**	
			No offset	Offset	No offset	Offset
Production (index; base solution = 100)	100	96	78	89	81	98
(share of production from ruminants)	(0.54)	(0.53)	(0.53)	(0.53)	(0.52)	(0.52)
Land use (base solution = 100)	100	97	69	88	70	79
(share of agricultural land that is tilled)	(0.87)	(0.87)	(0.88)	(0.87)	(0.82)	(0.92)
(kg nitrogen per ha; wheat/grass)	(155/194)	(155/192)	(155/188)	(155/192)	(141/186)	(151/232)
Measured agricultural support (base solution = 100)	100	94	75	85	73	98
Economic welfare (NOK billion)	18.7	21.4	26.5	22.9	26.0	23.1
Trade liberalization effects (Doha ceilings = 100)						
TAMS	202	62	6	25	2	94
Blue box	211	100	89	99	87	100
OTDS	195	73	36	51	33	91
GHG emissions (base solution = 100)	100	99	70	70	70	49
GHG emissions per hectare (ton CO_2 equiv. per ha in ag. activity)	(6.02)	(6.16)	(6.10)	(6.02)	(5.96)	(6.46)

4.2 Doha solution

One of the major aims of the on-going Doha Development Round is to reduce agricultural protection and to impose greater discipline on domestic agricultural subsidies, particularly those that are most trade distorting. The latest proposal for support reduction commitments was prepared by the previous chair of the WTO agriculture committee, Crawford Falconer (WTO, 2008). As already noted, for Norway the proposal restricts support in the main categories (TAMS, blue box and OTDS) to roughly one-half of recent levels. In addition, there are separate commitments with respect to specific policy instruments, e.g., export subsidies are to be eliminated and market access improved through reductions in tariffs and increases in tariff rate quotas (TRQs).

The impact of this proposal on Norwegian agriculture has been comprehensively analysed in Blandford et al. (2010). Column 2 in Table 2 shows the main results, including impacts on GHG emissions. Contrary to elevated expectations by the substantial cuts in the various categories of support, we see that the commitments can be met with only modest impacts on agricultural production, land use, and economic support. The reported 4 per cent decrease in production and 3 per cent decrease in land use can mainly be explained by the elimination of subsidised exports. Consequently, GHG emissions are virtually unaffected.

These small impacts are due to the fact that the proposed Doha disciplines are weak with respect to trade-distorting support (Orden et al., 2011). As explained in Blandford et al. (2010), there are important loopholes that can be exploited to avoid real changes in policies. In anticipation of a future agreement, Norway has already adopted or signalled future strategically adjustments designed to minimize the impact of a future WTO agreement on agricultural policy. The notified TAMS and blue box support have been reduced simply by shifting support to the green box in ways that involve no major change in policy. Furthermore, there are generous possibilities for defining sensitive product that are exempt from harsh cuts in import barriers. Most important, the market price component of the TAMS can be reduced by abolishing administered prices for selected products while maintaining real market price support through market access restrictions. There is also substantial flexibility for compensating producers through deficiency payments within the TAMS ceiling.

4.3 Further trade liberalization

Compared to the Doha proposal, more effective trade liberalization would be required if production is to change sufficiently to meet the GHG emission target. In this section we assume that farmers are confronted by the full effect of the elimination of export subsidies and expanded market access commitments at current subsidy rates. Import tariffs are reduced (proportionally) until the 30 per cent emission target is met. With reference to Figure 1, we move along the ray from point 1 and south-west to point 2 (no carbon offset) or point 3 (carbon offset), respectively. As the results in column 3 and column 4 in Table 2 show, the emission target is binding while the Doha trade commitments are met with a safe margin.

Agricultural activity is now more seriously affected. When carbon offsets are not allowed, production and land use decrease by 22 per cent and 31 per cent, respectively, compared to the current situation. If carbon offsets are allowed, production and land use are reduced by 11-12 per cent, i.e., agricultural activity can be kept at a higher level. As a consequence of trade liberalization, and lower agricultural activity, agricultural support falls (by 25 per cent in the no-offset case), and this contribute to increased economic welfare (NOK 7.8 billion). For a high cost country like Norway, this indicates that GHG abatement cost is negative in the sector if no value is attributed to agricultural activity beyond that determined by the world market price of food.

While the intensity in production relevant to emissions was represented by the capital/land ratio in the simple analysis in Section 2, the model provides other and more specific indicators, such as: (1) the share of production attributed to ruminants (ruminants cause high emissions per unit of production); (2) the share of land used in agricultural production that is regularly tilled (tillage emits carbon); and (3) the use of nitrogen per unit of land (emissions increase with the use of fertilizer). An aggregate indicator that incorporates these specific indicators is GHG emissions per hectare from agricultural production.

Based on these indicators, it can be seen that intensity in production is more or less unchanged compared to the base solution. The reason is that the abatement strategy used in this simulation, involves no major change in relative prices for production factors, but is merely based on a cut in producer prices. Consequently, substitution between low and high emission activities is more or less ruled out.

4.4 Carbon tax

A more targeted policy to reduce GHG emissions would involve an explicit tax on such emissions or an implicit tax generated by a cap-and-trade scheme with a binding cap on total emissions. These options, in contrast to the trade liberalization scenarios, will affect the relative prices of production factors. With the base solution as a point of departure, we introduce a NOK 300 tax per ton of GHG emissions (CO_2 equivalents). Also, to comply with the anticipated Doha agreement, we implement the specific export subsidy and market access commitments. Under these conditions, GHG emissions will, according to the model simulation, be below the emission ceiling. Consistent with the assumption that the authorities have a preference for maintaining a high level of agricultural activity, we scale up production proportionally until the desired emission target becomes binding.

Compared to the trade liberalization case, we see that production is higher than in the corresponding trade liberalization scenarios. In the no-offset case production increases from 78 to 81 per cent of the recent level. The anticipated substitution towards less emission-intensive activities also takes place in the no-offset case. Mainly as a result of reduced tillage and less use of fertilizer, emissions per hectare decrease by roughly 2 per cent. Although the effects are modest, the qualitative results conform to the situation set out in Figure 1 in terms of a movement from point 2 towards point 4.

When carbon offsets can be credited to agriculture's GHG account, the Doha trade agreement becomes binding rather than the GHG target. Aggregate production is maintained close to the present level, while emissions are reduced by about 40 per cent. Furthermore, factor intensity is reversed in the sense that less land is used per unit of output. With reference to Figure 1, this is analogous to a movement from point 3 towards point 5. GHG emissions per hectare increase by roughly 7 per cent as the soil is tilled more intensively.

An important conclusion revealed by these results is that when agricultural land can be used for significant carbon sequestration activities (i.e., the offset parameter λ is high) and when the resulting carbon offset can be credited to agriculture's GHG emissions account, there may be a strong tendency to intensify agricultural production, even if this leads to higher emissions from agricultural production *per se*.

5. Conclusion

In this paper we have dealt with strategies for complying with trade liberalization and GHG emission cuts from 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 the constraints imposed by multilateral agreements.

We demonstrate that trade liberalization implied by the Doha draft agreement on agriculture will not have a major impact on neither Norwegian agricultural production nor emissions; i.e., the proposed 30 per cent cut in GHG emissions will not be reached. Consequently, more effective trade liberalization or carbon taxes are required. While both these measures will reduce agricultural activity (trade liberalization more than carbon taxes), economic welfare increases. For a high cost country like Norway, this indicates that GHG abatement cost is negative in the sector if no value is attributed to agricultural activity beyond that determined by the world market price of food.

The analysis shows, as a main result, that the impacts on agricultural activity of the proposed emission cut depend substantially on whether the climate agreement credits for carbon sequestration (carbon offsets) on land taken out of agricultural production. According to the model simulations, aggregate production can be kept 15-20 per cent higher when carbon offsets are credited. Furthermore, while a carbon tax in the no-offset case provides incentives to substitute towards less emission-intensive activities, factor intensity is, in the offset case, reversed in the sense that emissions per unit of land increases. The intuition of this result is that production factors that increase land productivity (e.g., fertilizer and tillage) also tend to increase emissions per land unit, so that an intensification of production (less land per produced unit) may release land for offset activities.

A more general conclusion revealed by these results is that when agricultural land can be used for significant carbon sequestration activities and when the resulting carbon offset can be credited to agriculture's GHG emissions account, there may be a strong tendency to intensify agricultural production, even if this leads to higher emissions from agricultural production *per se*.

References

Blandford, D., I. Gaasland, R. Garcia and E. Vårdal (2010). 'How Effective are WTO Disciplines on Domestic Support and Market Access for Agriculture?' *The World Economy*, pp. 1470-1485.

Brunstad, Rolf J., Ivar Gaasland and Erling Vårdal (1995). "A Model for the Agricultural Sector in Norway", Working Paper No. 25/95, Bergen: Foundation in Economics and Business Administration.

Brunstad, Rolf J., Ivar Gaasland and Erling Vårdal (1999). "Agricultural Production and the Optimal Level of Landscape Preservation", *Land Economics*, Vol. 75 (4), 538-546.

Brunstad, Rolf J, Ivar Gaasland and Erling Vårdal (2005). "Multifunctionality of agriculture: an inquiry into the complementarity between landscape preservation and food security", *European Journal of Agricultural Economics*, Vol 32 (4), pp. 469-488.

Central Intelligence Agency (2011). The World Factbook. https://www.cia.gov/library/publications/the-world-factbook Accessed: February 5, 2011.

Gaasland, I. and S. Glomsrød (2010), 'Miljøindikatorer i Jordmod', forthcoming as working paper (Bergen: SNF).

McCarl, B. A., and T. H. Spreen (1980). "Price Endogenous Mathematical Programming as a Tool for Sector Analysis", *American Journal of Agricultural Economics* (Vol. 62), pp.87-107.

Mittenzwei, K. and I. Gaasland (2008), ’Dokumentasjon av JORDMOD- modellbeskrivelse og analyse’, NILF-rapport no. 3, Oslo: Norwegian Agricultural Economics Research Institute, Oslo.

NILF (2007), *Norwegian Agriculture: Status and trends, 2007.* Oslo: Norwegian Agricultural Economic Research Institute.

OECD (2010), *Agricultural policies in OECD countries: monitoring and evaluation, 2010* (Paris: Organization for Economic Cooperation and Development).

Orden, David, Blandford, David and Tim Josling (2011). *WTO Disciplines on Domestic Agricultural Suppor*, London and New York: Cambridge University Press.

Wreford, A., D. Moran and N. Adger (2010), *Climate Change and Agriculture: Impacts, Adaptation and Mitigation,* Paris: OECD.

WTO (2008), ‘Revised draft modalities for agriculture’, Document no. TN/AG/W/4/Rev.4 Geneva: World Trade Organization, WTO Secretariat, Committee on Agriculture, Special Session, 6. December 2008.