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Impact Of Greenhouse Gas Abatement Targets On Agricultural Activity

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Abstract

As part of its continuing commitment to address the causes of climate change, the EU has agreed reduction targets for greenhouse gas (GHG) emissions to be achieved by 2020. In the case of Ireland the target is a reduction of 20 percent relative to the 2005 level. Agriculture is a major source of GHG emissions in Ireland, comprising 26.8 percent of total GHG emissions in 2007. Understanding the scale and cost of the decrease in agricultural production required to achieve this reduction in GHG emissions is particularly important, as is the comparison of the cost of this approach with a range of possible other means of achieving emissions reductions in the sector. This study finds that, even with reduced fertiliser usage and more extensive production practices, a very substantial decrease in the livestock population is required to meet the emission reduction targets by 2020. The paper concludes that a solution involving a mix of measures may ultimately be required.

Keywords, agriculture, policy analysis, partial equilibrium modelling, baseline, scenario analysis, GHG, Kyoto, climate, Ireland, FAPRI, EU Gold Model, abatements

JEL codes: Q11, Q17, Q18, Q54

1 Introduction

Reflecting growing international concern about climate change, the Kyoto Protocol[1] was signed in Japan in 1997. It resulted in specific limitations for Greenhouse Gas (GHG) emission levels to be achieved by the first commitment period 2008 - 2012 in countries that are signatories to the agreement. These targets were set with reference to GHG levels in 1990. Most developed countries must reduce their GHG emissions below the 1990 level to comply with the Protocol, but Ireland received a concession that allowed an increase in its GHG emissions by a further 13 percent above the 1990 levels by the first commitment period. Despite this concession, Ireland was not able to meet its target for the first commitment period, causing the government to set out specific measures to control GHG emissions.

The political desire to reduce our impact on the climate has now come to the fore both in Ireland and in the EU generally. GHG emission reduction targets have now been established for Ireland and other Member States as part of the effort sharing agreement reached in Brussels in December 2008 (European Council, 2008). For Ireland, at a minimum, the target is a reduction of 20 percent by 2020 in overall GHG emissions from all sectors of the economy, relative to the 2005 level. The reduction target would increase to 30 percent if a successor agreement to the Kyoto protocol is achieved (European Council, 2008).

The scope of this analysis was restricted to the Irish agricultural sector and its focus was on the costs to the sector of meeting hypothetical emissions reduction targets. The FAPRI-Ireland global commodity model was referenced to determine domestic agricultural output levels, but issues such as carbon leakage were not explicitly considered. While the modellers agree that the effects of carbon leakage could be significant when accounting for GHGs *globally*, this does not change the fact that Ireland has obligations to meet which are defined in terms of *national* emissions. The goal of this project was to cost the fulfilment of these obligations.

2 Background

Relative to other EU member states and most other developed countries, Ireland is unusual in terms of the percentage contribution made by agriculture to national GHG emissions. Of the 69.21 Mt of the CO_2 equivalent produced in Ireland in 2007, it is estimated that 26.8 percent, or 18.557 Mt, was contributed by Irish agriculture (EPA, 2009). This figure reflects both the high degree of agricultural activity and relatively lower levels of other GHG sources (such as heavy industry) in Ireland. The emission of GHGs from Irish agriculture principally comes from animals but is also the result of agricultural practices such as the use of fertiliser and manure management. Of note in the current accounting methodology is the exclusion from the sector all of those emissions resulting from the transport and processing of agricultural goods, as well as the manufacture and operation of farm machinery and equipment. These emissions are accounted for in other sectors.

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[1] See the US Department of State, Bureau of Oceans and International Environmental and Scientific Affairs (1998) for more details.

Unlike some other sectors of the economy, agriculture is not part of the Emissions Trading Scheme (ETS) and thus there are no measures in place at present that would lead to a reduction in agricultural GHG emissions. Agriculture represented about 40 percent of emissions in the non-ETS sector in 2006 (EPA, 2008). With this large share of non-ETS emissions, insulating agriculture from any GHG emissions reduction requirement would be controversial, as it would require other non-ETS sectors to make greater emission reductions

Given all of the above, and despite the recent downward trend for GHG emissions from agriculture, the sector will almost certainly have to bear at least some of the burden of meeting the 2020 reduction targets. There is thus a need to estimate GHG emissions from agriculture and the cost of achieving those reductions.

2.1 Reduction strategies: Technological Innovation vs. Production Cutbacks

There are two main avenues available to the agricultural sector through which it may accomplish the necessary reductions in emissions. Namely, these are through technological innovation or alternatively through production cutbacks. Of these, the former is only likely to contribute in a significant way in the long term. The latter option is simultaneously the more realistic and the more controversial method of the two in the short to medium term.

Technological innovation could potentially reduce overall emissions by decreasing emissions per unit of output (e.g. CO_2 equivalent per litre of milk). If the same quantity of agricultural goods can be produced at a lower level of emissions, emissions reductions would be less problematic for the industry and the wider economy. However, if the new technology also results in an expansion of production on a large enough scale, then overall emissions from the sector could remain at the current level or even increase.

The main technological developments available to the market now either involve the purchase of expensive machinery, or employing more extensive farm practices. Widespread adoption of new capital equipment is not likely to occur quickly, owing to the high investment cost and the need for current capital to depreciate. On the other hand, reducing the use of feeds and fertilizers, along with improving some other farm practices are innovations which can be adopted sooner and at a lower cost. However, the gains from these improvements are likely to be small relative to the reduction targets. This suggests that technological innovation is not likely to be a significant factor in the short to medium term, although it certainly can contribute to emissions reductions.

The only other route available to the industry is to cut back heavily on production, particularly in the bovine populations. This is due to the large contribution of the ruminant digestion processes of cattle to the production of CH_4 in the sector. Such a cutback would be painful for the industry and the economy at large, but even this measure could not be implemented overnight. The cutback would have to occur over

several years, as farmers simply disinvest in livestock rather than slaughtering large numbers of animals and flooding the market with more meat products than it could absorb.

3 Methodology

3.1 FAPRI-Ireland Commodity Model

The FAPRI GHG model is used in this study. It is a sister component of the FAPRI-Ireland model and FAPRI EU-GOLD commodity model described in Hanrahan (2001). The FAPRI commodity models allow projections of future levels of agricultural activity and the FAPRI GHG model then uses a mix of national and default emissions factors to convert this activity to estimates of annual GHG emissions from now to 2020.

The FAPRI-Ireland model is a set of econometric, dynamic, multi-product, partial-equilibrium commodity models. In its current version, the model has an agricultural commodity coverage that extends to markets for grains (wheat, barley and oats), other field crops (potatoes, sugar beet and vegetables), livestock (cattle, pigs, poultry and sheep) and milk and dairy products (cheese, butter, whole milk powder and skim milk powder). Many of the equations in the model are estimated using annual data from the period 1973–2007 or over shorter periods in cases where data are not available or where, for policy reasons, longer estimation periods would not be meaningful.

The FAPRI-Ireland model is structured as a component of the FAPRI EU GOLD model, which is a commodity model of EU agriculture. The GOLD model in turn can form a component of the FAPRI world modelling system for world agriculture. In this way the model for Ireland can incorporate the consequences of changes in international trade policy as they relate to agriculture.

The primary purpose of the FAPRI-Ireland model is to analyse the effect of policy changes on economic indicators such as the supply and use of agricultural products, agricultural input expenditure and sector income. In so doing the model produces future projections of animal numbers, input usage volumes (e.g. fertiliser, feed, fuel, energy) and other indicators. These data can be incorporated into the satellite GHG models to enable the provision of base data and projections relating to multifunctionality indicators, such as GHG emissions, fertiliser usage and ammonia emissions. Key components of the structure of the partial-equilibrium model are set out below.

The equation for the total agricultural area farmed is modelled as:

$$taf_t = f\left(agout_{t-1} \middle/ gdp_{t-1} \right) \tag{1}$$

where taf_t is the total agricultural area in year t and $agout_{t-1}$ is the value of agricultural output in year $t-1$ and gdp_{t-1} is a measure of national income in year $t-1$. The equations used to determine the share of the total agricultural area farmed within each agricultural culture group can be expressed as:

$$ash_{i,t} = f\left(ret_{i,t-1}, agout_{t-1}, ash_{i,t-1}, V_t, Z_t\right) \qquad i = 1, \ldots, 5 \qquad (2)$$

where $ash_{i,t}$ is the share of the total agricultural area to be allocated to i-th culture group in year t, $ret_{i,t-1}$ is the value of the output from the i-th culture group and $agout_{t-1}$ is the value of total agricultural output in year $t-1$, while V and Z are vectors of exogenous and endogenous variables that could have an impact on the area allocated to agriculture culture group i. The land use associated with one of the five agriculture culture groups modelled (pasture, hay and silage, potatoes, sugar beet and cereals) is derived as the residual land use so as to ensure land-use balance.

The total area allocated to the i-th agricultural culture group is then derived as the product of the i-th area share times the total agricultural area:

$$af_{i,t} \equiv ash_{i,t} * taf_t \qquad (3)$$

Within each of the i agricultural culture groups, land may be further allocated among competing cultures, for example within the land area allocated to the cereals culture group soft wheat 'competes' with barley and oats for land. Within the culture group allocation of land this is modelled using area allocation equations of a similar form to (2):

$$asf_{i,t}^{j} = f\left(ret_{i,t-1}^{j}, \sum_{\substack{k=1 \\ k \neq j}}^{m} ret_{i,t-1}^{k}, asf_{i,t-1}^{j}, S_t, W_t\right) \qquad j, k = 1, \ldots, m \qquad (4)$$

where $asf_{i,t}^{j}$ is the share of the j-th culture within the culture group i, $ret_{i,t-1}^{j}$ is the return to the j-th culture in year $t-1$, and S_t and W_t are other endogenous and exogenous variables that may affect the allocation of land among the j competing cultures within any given culture group i. The land (in hectares) allocated to the j-th culture is then derived as the product of the total land allocated to the i-th culture group ($af_{i,t}$) times the area share ($asf_{i,j,t}$):

$$aha_{i,t}^{j} \equiv asf_{i,t}^{j} * af_{i,t}. \qquad (5)$$

The yield equations of culture j in culture group i can be written as:

$$r_{i,t}^{j} = f\left(p_{i,t-1}^{j}, r_{i,t-1}^{j}, V\right) \qquad j = 1, \ldots, n \qquad (6)$$

where $r_{i,t}^{j}$ is the yield per hectare of culture j belonging to the culture group i, and V is a vector of variables, which could influence the yield per hectare of the culture being modelled.

On the demand side, crush and feed demand and non-feed use per capita are modelled using the following general functional forms:

$$Fu_{i,t}^{j} = f\left(p_{i,t}^{j}, p_{i,t}^{k}, Z\right) \qquad j, k = 1, \ldots, n \qquad (7)$$

where $Fu_{i,t}^{j}$ is the feed demand for culture j belonging to the culture group i and Z is a vector of endogenous variables (such as the level of meat production), which could affect the feed demand ;

$$NFu_{i,t}^{j} = f\left(p_{i,t}^{j}, NFu_{i,t-1}^{j}, V\right) \qquad j, k = 1, \ldots, n \qquad (8)$$

where $NFu_{i,t}^{j}$ is the non-feed demand for culture j belonging to the culture group i and V is a vector of exogenous variables, such as income, that could have an impact on non feed demand;

$$CR_{i,t}^{k} = f\left(p_{i,t-1}^{h}, p_{i,t-1}^{h}, p_{i,t-1}^{l}, CR_{i,t-1}^{h}\right) \quad h, l = 1,...,n \tag{9}$$

where $CR_{i,t}^{k}$ is the crush demand for oilseed culture k and $p_{i,t-1}^{h}$ is the real price of considered seed oil and $p_{i,t-1}^{l}$ is the real price of the seed meal produced as a product of the crushing process.

While the structure of individual livestock sub-models varies, their general structure is similar and is presented below. Ending numbers of breeding animals can be written as:

$$cct_{i,t} = f\left(cct_{i,t-1}, p_{i,t}, V\right) \quad i = 1,...,n \tag{10}$$

where $cct_{i,t}$ is the ending number in year t for the breeding animal type i, $p_{i,t-1}$ is the real price in year $t-1$ of the animal culture i considered, and V is a vector of exogenous variables that could have an impact on the ending inventory concerned (such as the direct payment linked to the animals concerned or specific national policy instruments).

Numbers of animals produced by the breeding herd inventory can be written as:

$$spr_{i,t} = f\left(cct_{i,t-1}, ypa_{i,t}\right) \quad i = 1,...,n \tag{11}$$

where $spr_{i,t}$ is the number of animals produced from breeding herd $cct_{i,t}$ in year t and $ypa_{i,t}$ is the exogenous yield per breeding animal concerned.

Within each animal culture i there may be m categories of slaughter j. The number of animals in animal culture i that are slaughtered in slaughter category j can be written as:

$$ktt_{i,t}^{j} = f\left(cct_{i,t}^{j}, p_{i,t}, z_{i,t}^{j}, V\right) \quad i = 1,...,n \quad j = 1,...,m \tag{12}$$

where $ktt_{i,t}^{j}$ is the number of animals slaughtered in category j of animal culture i in year t, $z_{i,t}^{j}$ is an endogenous variable that represents the share of different categories of animals slaughtered in the total number of animals slaughtered for the animal culture concerned, and V is a vector of exogenous variables.

Ending stocks of animals (breeding and non-breeding) are derived using identities involving initial inventories of animals, animal production (births), slaughter, and live exports and imports.

The number of dairy cows can be written as:

$$cct_{t} = f\left(p_{t}, V\right) \tag{13}$$

where cct_{t} is the ending number of dairy cows in year t, p_{t} is the real price of milk in year t, and V is a vector of exogenous variables that could have an impact on the ending inventory concerned (such variables include policy instruments such as the milk quota). Milk yields per cow can be written as:

$$r_{t} = f\left(p_{t}, V\right) \tag{14}$$

where r_{t} is the milk yield per cow, p_{t} is the real price of milk in year t, and V is a vector of variables, which could influence the yield per cow.

3.2 Quantifying Emissions: The GHG Extension

Due to the many diffuse sources of emissions on any given farm, direct quantitative data on GHG emissions are not available. For this reason, it is necessary to approximate the levels of gases emitted by the sector using generalized relationships between production and emissions which are based on the latest scientific research.

The IPCC methodology for governments to make such approximations was proposed by Houghton et al. (1996). The approach essentially involves applying conversion coefficients to agricultural data and calculating the associated emissions of GHGs from enteric fermentation, manure management practices and agricultural soil management as defined by Houghton et al. (1996). These conversion coefficients and emission factors may be modified with country specific coefficients where supporting research has been carried out.

Considerable work has been done to provide GHG emission factors which are specific to Ireland, notably the work by O'Mara et al. (2006). As a result, the Environmental Protection Agency (EPA) currently uses a mixture of default and country specific emission factors in the calculation of GHG inventories.

As a final step in the IPCC methodology, all different GHGs are converted to a common measure. The common measure used is CO_2 equivalent, which can be calculated using a conversion coefficient called a Global Warming Potential (GWP). GWPs are specific to each gas, and they reflect the differences in potency caused by the gases varying chemical structures. In this way small changes in the level of a gas with a high GWP will have a disproportionately large effect on the overall level of CO_2 equivalent.

Data on Irish livestock numbers, enterprise areas and input applications have been obtained from the FAPRI-Ireland model. Livestock emission factors are expressed in terms of the annual amount of methane produced by the animal. These emission factors vary by animal type, not only because of their differing size and feed consumption, but also because of the manner in which food is digested and the animal manure is subsequently treated.

Concerning manure management, the nature of production systems tends to favour the management of cattle and pig manure in liquid systems, which facilitate anaerobic respiration and the emission of methane. By contrast, sheep are rarely housed and consequently methane emissions from their manure are negligible.

The emission of GHGs from agricultural soils varies in accordance with the manner in which the land is managed, which in turn depends on the type of crop production system in place. For the purposes of emissions calculations, the IPCC categorises farmland under three uses. Crop land and more intensively farmed grassland have quantities of fertiliser applied to them, whereas less intensively farmed grassland may have no fertiliser applied to it. Consequently, the levels of methane and nitrous oxide emissions from cropland and more intensively farmed grassland are considerably higher than grassland maintained without fertiliser.

GHGs in the form of methane and nitrous oxide emissions from each agricultural sub-sector i are thus a function of the number of animals, crop areas harvested and nitrogen application. Since the global warming potential of CH_4 and N_2O differ, for the purpose of their addition these are brought to a common base of CO_2 equivalents using standard weighting systems. CH_4 produced in each agricultural sector can be represented as:

$$CH_{4,i,t} = f\left(q_{i,t}, \alpha_i\right)$$
(13)

where $CH_{4,i,t}$ is the total amount of CH_4 produced by sector i in year t, q is the quantity of animal or crop category i in year t and α is the methane conversion coefficient associated with the animal or crop category i. Similarly, N_2O produced in each agricultural sector can be represented as:

$$N_2O_{j,t} = f\left(q_{j,t}, \beta_j\right)$$
(14)

where $N_2O_{j,t}$ is the total amount of N_2O produced by sector j in year t, q is the quantity of animal or crop category j in year t and β is the nitrous oxide conversion coefficient associated with the animal or crop category j.

Finally, total GHG emissions in the common base of CO_2 equivalents can be expressed as:

$$EquivCO_{2_t} = \delta \sum_{i=1}^{n} CH_{4,i,t} + \gamma \sum_{j=1}^{m} N_2O_{j,t}$$
(15)

where $EquivCO_2$ is CO_2 equivalent , while $\delta = 21$ and $\gamma = 310$ are the global warming potentials of methane and nitrous oxide respectively.

4 Results

The projected level of agricultural activity related to the policy assumptions in the model is estimated, creating a reference GHG emission scenario for each year to 2020. This provides an estimate of the distance agriculture would be from the GHG reduction target if no policies to address GHG emission in agriculture are pursued.

The model assumes no new World Trade Organization agreement. Furthermore, the series of 1 percent expansions in the Milk Quota continues until eventual elimination in 2015. Since this is a partial equilibrium model, sectors other than agriculture are taken to be exogenous.

In the GHG emission reduction scenario we estimate the reduction in Irish agricultural output required to reduce GHG emissions from the sector to the target level by 2020. This scenario assesses the constraints on production that would be required to achieve a possible 30 percent GHG reduction target and provides estimates of the economic impact of meeting the target for Irish agriculture.

No consideration was given to different types of policy vehicles by which these reductions could be achieved, nor was any given to administrative or transaction costs.

Technical development is assumed to have a negligible impact on the emissions from production during the projection period. Therefore, stock reductions (particularly in

suckler cows) are the principle means through which emissions are reduced. These reductions are assumed to occur gradually and are subject to biological restrictions.

GHGs are accounted for 'at the farm gate' so food processing and transport are not part of the sector as defined in the model. This is in accordance with IPCC's methodology.

Finally, the GHG inventories are calculated for the Irish agricultural sector, after the outputs from the sector are calculated for the year. This being the case, the model is not equipped to deal with issues such as carbon leakage or domestic carbon shifting.

A 30 percent GHG reduction target implies a target level of emissions from Irish agriculture in 2020 of 13.29 Mt CO_2 equivalent (exclusive of emissions by agriculture from fuel combustion). Such a reduction in emissions could not occur overnight and is assumed to takes place gradually from 2011 to 2020. It is assumed in this analysis that the reductions in emissions required to achieve the 30 percent reduction target are achieved through a reduction in the number of beef cattle (i.e. suckler cows, and their progeny). Using the models it is also possible to look at a range of other options (reductions in the number of dairy cows, sheep etc.).

In the reference scenario GHG emissions decrease by 8.5 percent from 18.9 Mt CO_2 equivalent in 2005 to 17 .3 Mt CO_2 equivalent in 2020. While there is a decrease in drystock numbers, in the absence of milk quotas, this is almost entirely offset by an increase in the number of dairy cows (which increase by almost 10 percent) and their progeny. Suckler cow numbers drop by 23 percent over the period 2005 to 2020. The total cattle population (all bovine categories) falls by 9 percent over the period 2005 to 2020.

In the reduction scenario, to reach the 2020 30 percent emission reduction target of 13.29 Mt CO_2 equivalent, Irish cattle numbers are reduced to 4.56 million head by 2020 with suckler cows numbers reduced by 2020, to just over 350,000 head.

Accordingly, by 2020 Irish beef production decreases to 0.38 Mt to achieve the reduction target (beef production was 0.58 Mt in 2005 and is projected to be 0.49 Mt under the reference scenario in 2020). By 2020 the value of the beef sector under the 30 percent GHG reduction target is 23 percent lower than the 2005 level.

Table 1.   Percentage change in bovine numbers, beef production and value of beef output

	2020 Reference v 2005	2020 GHG Minus 30 percent v 2005
	percent change	
Total Cattle	- 9.4	- 34.7
Dairy Cows	9.5	9.5
Suckler Cows	- 22.6	- 71
Beef Production	- 15.5	- 34.5
Beef Sector Value	7.1	- 22.6

Source: FAPRI-Ireland GHG Model

5 Conclusion

Agricultural policy is likely to contribute to a reduction in GHG emissions from agriculture over the next decade. However, even with such a reduction the level of emissions from agriculture is likely to be well above the possible 30 percent GHG emission reduction target the sector could face. Our results illustrate the dramatic impact which meeting a 30 percent GHG emission reduction target would have on the Irish beef sector, if a limit on suckler cow numbers was introduced,. Effectively, the constraint imposed by the GHG emission reduction target would mean that by 2020, two thirds of the existing suckler cow population and their progeny would no longer exist. It is questionable whether such a radical policy could be pursued, and as a result a mix of measures to achieve emissions reduction in the sector will most likely be required.

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