The Rural Economy Research Centre

Working Paper Series

Working Paper 10-WP-RE-11

Modelling the impact of the recession on greenhouse gases from agriculture in Ireland

Patrick R. Gillespie *, Trevor Donnellan , and Kevin Hanrahan

Teagasc, Athenry, Co. Galway, Ireland

For More Information on the RERC Working Paper Series
Email: Cathal.odonoghue@teagasc.ie,
Web: www.tnet.teagasc.ie/rerc/

Modelling the impact of the recession on greenhouse gases from agriculture in Ireland

Patrick R. Gillespie *, Trevor Donnellan , and Kevin Hanrahan

Abstract

The effects of the recession of 2009 have been felt across the economy of Ireland. The rapid contraction in economic activity has had its effect on greenhouse gas (GHG) emissions as well. It is possible to model the recession's effect on agricultural GHG in the FAPRI-Ireland GHG model using the latest international commodity price projections from Food and Agricultural Policy Research Institute (FAPRI). The FAPRI-Ireland GHG model creates projections of future levels of Irish agricultural activity and then uses a mix of national and default emissions factors to convert this activity to estimates of annual GHG emissions from now to 2020. Our model is shocked using post-downturn commodity price projections for a selection of exogenous prices. The changes to these international commodity prices reflect the international market response to the downturn, and as such they have an impact on the level of GHG emitted by the agricultural sector in Ireland. This analysis finds that, despite the depth and breadth of the recession, the impact on GHG emissions from Irish agriculture has been muted. The impact of the shock is to reduce the projected annual emissions from the sector by only 0.14 Mt by 2020. This compares to the 2.97 Mt reduction in annual emissions which the sector would have to achieve if, for example, a reduction target of 20 percent on 2005 levels were to be imposed.

Keywords: agriculture, partial equilibrium modelling, baseline, impact analysis, GHG, Kyoto, climate, Ireland, FAPRI, EU Gold Model, abatement

Corresponding Author: Patrick R. Gillespie
Email: patrick.gillespie@teagasc.ie

I.1 The Importance of Agriculture

The public discourse on climate change policy often centres on images of chimney stacks and car exhaust pipes. This focus on industry, energy and transport is understandable as these are major sources of carbon dioxide (CO_2) emissions. However, two other greenhouse gases (GHG) are mainly attributable to agricultural production, both of which are actually more potent than CO_2. This means that the agricultural sector is also an important contributor of greenhouse gases in most of the world's developed economies (IPCC, 2007).

Ireland's GHG emissions profile is unusual in that agricultural activity is such a prominent source of emissions. According to the Environmental Protection Agency (EPA, 2010a), of the 67.44 million tonnes of CO_2 equivalent (Mt CO_2e) GHG emitted by Ireland in 2008, 27.3 percent, or 18.43 Mt[1] of this amount is attributed to Irish agricultural production. This percentage is large when compared to analogous figures for other developed nations, and it reflects both the high degree of agricultural activity and relatively lower levels of other GHG sources (e.g. heavy industry) in Ireland.

One may examine Irish agriculture's contribution to european agricultural emissions as a means to put Irish emissions into context; the 17.76 Mt CO_2e produced by the sector in 2007 (EPA, 2009b) contributed to the approximately 462 Mt CO_2e emitted by agriculture in the EU-27 member states in this, the latest year reported by the European Environment Agency (EEA, 2009, 16, Table ES.4). Agriculture in the narrower group of EU-15 member states emitted 371 Mt CO_2e during the same period (Ibid., Table ES.7)[2]. Therefore, emissions from Irish agriculture constitute 3.84 percent of agricultural GHG emissions from the EU-27, and 4.79 percent of agricultural GHG emissions from the EU-15. However, for these percentages to be meaningful one must consider them in tandem with population figures for their respective areas. The estimate for combined population of the EU-27 by the end of 2007 was 497.46 million people, or 321.52 million people for the EU-15. The corresponding estimate for Ireland was 4.40 million people (Lanzieri, 2008). This puts the population of Ireland as a percentage of the EU-27 and the EU-15 at 0.89 percent and 1.37 percent respectively. The Statistical Office of the European Communities (Eurostat) also keeps series for various livestock population figures (Eurostat, 2010), and a similar calculation as above yields the population of cows in the State expressed as a percentage of the european cow population.

---

[1] The established accounting methodology excludes from the agricultural sector of all those emissions resulting from the transport and processing of agricultural goods, as well as those emissions resulting from the manufacture and delivery of farm machinery. This means that the percentages cited above actually understate the total contribution of agricultural activities to Irish GHG emissions. However, because this methodology is consistent with that which is followed by countries around the globe, the Irish agricultural sector's standing relative to those from other countries remains the same.

[2] Note that the figures are reported in teragrams (Tg) which are equivalent to million tonnes (Mt).

Table I.1. Irish Agricultural GHG Emissions relative to the EU

	% of EU-27	% of EU-15
Human Population**	0.89	1.37
Agricultural GHG Emissions*	3.84	4.79
Cow Population**	6.03	7.38

* Source: European Environmental Agency. As measured in CO_2e
** Source: Eurostat

These figures reflect the fact that Ireland is a substantial net exporter of agricultural products, and that its agricultural sector is centred on ruminant animals whose digestive processes are a key source of GHG emissions.

Of all categories of livestock, cattle is the largest contributor of GHG emissions. Regarding the varying contribution of different livestock populations the Environmental Protection Agency says this in its National Inventory Report for 2009,

> ‘Methane emissions from […] *Enteric Fermentation* and […] *Manure Management* are dependant on the type and number of livestock present on farms and in Ireland’s case, the amounts are largely determined by a large cattle population [….] Cattle account for almost 90 percent of annual CH_4 emissions in Irish agriculture. The emissions of N_2O from the Agriculture sector follow similar trends to those of CH_4 because cattle also largely determine the amount of nitrogen inputs to agricultural soils from synthetic fertilizer and animal manures which produces the bulk of N_2O emissions.’ (p. 33)

Irish agriculture’s orientation towards livestock production for export means the majority of agricultural land is grassland, and most of this is associated with bovine production systems. Therefore, usage of synthetic fertilisers is also closely tied to the size of the national herd because the use of these fertilisers is one strategy for increasing grassland yield per hectare, and hence livestock productivity.

The need for specific climate policies stems in part from the signing of the Kyoto Protocol in 1997 (Information Unit on Climate Change, 1998). This resulted in specific limitations for GHG emission levels to be achieved by the first commitment period 2008 - 2012 in countries that are signatories to the agreement. Most developed countries are obliged to 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 these levels by the first commitment period. Despite this concession, Ireland was not able to meet its target by the start of the first commitment period, causing the government to set out specific measures to control GHG emissions.

Projections in this area have changed somewhat in the recent past, due to the effects of the severe global recession. The ‘gap’ between the Kyoto target and the EPA’s latest ‘with additional measures’ projection (i.e. that which incorporates existing and planned policies) stands at -0.5 Mt per annum. This means that Ireland would more than meet its reduction target. As a consequence, the State has already obtained enough carbon credits to meet its Kyoto obligations by the end of the first commitment period in 2012. (EPA, 2010b, pp. 16)

However, the Kyoto Protocol is not the only international agreement to which Ireland is bound in this policy area. In addition, the member states of the European Union have also pledged themselves to more ambitious reduction targets under the EU 20-20-20 agreement (DECISION 406/2009/EC). This agreement obligates Ireland to a 20 percent reduction in GHG emissions relative to its 2005 level, and this requirement could be strengthened to accommodate a 30 percent reduction across the entire EU in the event that a successor treaty to the Kyoto Protocol is agreed. With growth expected post-2012 Ireland is still projected to fall short of its current emissions reduction target under this agreement.

If Ireland is to meet its obligations under EU 20-20-20 agreement then the importance of reducing agricultural emissions is apparent, given the sector's contribution to the national emissions total. This means that there is perhaps even a greater need to employ a detailed and reliable model of GHG emissions from the agricultural sector in this country than there is in other developed nations. This need is made all the more pressing by virtue of the fact that climate targets and abatement policies for the agricultural sector have yet to be identified.

I.2 The Irish Agricultural Emissions Model

Projecting Commodities and Activity Levels

The FAPRI-Ireland Agricultural Emissions Model is a sister model of the FAPRI-Ireland model and FAPRI EU-GOLD commodity model described in Hanrahan (2001). The 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 1973–2008 or over shorter periods in cases where data are not available or where, for policy reasons, longer estimation periods would not be meaningful. Where appropriate, synthetic parameters are used.

There are 403 equations specified in the latest version of this model. This being the case, we have deemed it more instructive to highlight some of the more important classes of equations in general form rather than to provide an exhaustive list. To this end, the equation for the total agricultural area farmed is modelled as

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

where; taf_t is the total agricultural area in year t, $agout_{t-1}$ is the value of total 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, $agout_{t-1}$ is the value of total agricultural output in year $t-1$, and the vectors of exogenous and endogenous variables that could have an impact on the area allocated to agriculture culture group i are denoted by V and Z.

The land use associated with one of the five agriculture culture groups modelled 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

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

Within each of the 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 form similar to (2); i.e.

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

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 the other endogenous and exogenous variables that may affect the allocation of land among the j competing cultures within any given culture group i are S_t and W_t.

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 $asf_{i,j,t}$ as in

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

The yield equations of culture in culture group 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 that could have an impact on non feed demand.

Whilst 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

$$cct_{i,t} = f\left(cct_{i,t-1}, p_{i,t}, V\right) \qquad i = 1,\ldots,n \qquad (9)$$

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.

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

$$spr_{i,t} = f\left(cct_{i,t-1}, ypa_{i,t}\right) \qquad i = 1,\ldots,n \qquad (10)$$

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. The number of animals in animal culture that are slaughtered in slaughter category j can be written as

$$ktt_{i,t}^{j} = f\left(cct_{i,t}^{j},\, p_{i,t}, z_{i,t}^{j}, V\right) \quad i = 1,\dots,n \quad j = 1,\dots,m \qquad (11)$$

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

$$cct_t = f\left(p_t, V\right) \qquad (12)$$

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.

Milk yields per cow can be written as

$$r_t = f\left(p_t, V\right) \qquad (13)$$

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.

Calculating GHG Emissions

The calculation methodology for GHG emissions in this model was designed to concur with that set out by the EPA in its National Inventory Report (EPA, 2009a). The emission factors for enteric fermentation and manure management in cattle production have been adjusted to reflect the set of typical conditions and prevalent farm practices which exist in Ireland. These adjustments have resulted in an increase in both detail and accuracy relative to calculations based on the 'default' IPCC emission factors.

The potency of each of the different gases concerned varies substantially, so it is necessary to bring them to a common base of CO_2 equivalents using coefficients called global warming potentials[3]. Levels of gases can then be compared and aggregated for the purposes of policy analysis and environmental accounting. Total GHG emissions in the common base of CO_2 equivalents can be expressed as

$$EquivCO_{2t} = \delta \sum_{i=1}^{n} CH_{4,i,t} + \gamma \sum_{j=1}^{m} N_2O_{j,t} \qquad (14)$$

where; $EquivCO_2$ is the CO_2 equivalent figure for combined gases, δ is a constant called the global warming potential of methane which is equal to 21, and γ is a constant called the global warming potential of nitrous oxide which is equal to 310.

Of the two relevant gases from the sector, emissions in the form of methane (CH_4) are more prevalent at between 57 and 60 percent of total emissions as expressed in terms of CO_2 equivalent. Emissions of CH_4 are primarily due to enteric fermentation processes in livestock, making up 80 percent of emissions of the gas. Methane from enteric fermentation accounts for anywhere between 46 and 48 percent of total emissions.

Beef and dairy production are the most important agricultural activities in Ireland in terms of both output and GHG emissions. Combined with the importance of CH_4 as a gas, and enteric fermentation as a source category for that gas, it seems fitting to start our discussion of GHG calculations with CH_4 from enteric fermentation in the cattle categories.

CH_4 from enteric fermentation is a function of the number of head in the relevant livestock population and that population's associated emission factor. The general form for the calculation of CH_4 in the model is:

$$CH_{4,i,t} = f\left(q_{i,t}, \alpha_{i,t}\right) \qquad (15)$$

This form can be specified for any cattle category by applying the appropriate subscript for i, as in

$$CH_{4,DC,t} = f\left(q_{DC,t}, \alpha_{DC,t}\right) \qquad (16)$$

---

[3] The EPA provides this explanation of Global Warming potentials in the National Inventory Report for 2009 (pg. 5):

> 'The GWP of a gas is a measure of the cumulative warming over a specified time period, e.g. 100 years, resulting from a unit mass of the gas emitted at the beginning of that time period, expressed relative to an absolute GWP of 1 for the reference gas carbon dioxide (IUCC, 1998). The mass emission of any gas multiplied by its GWP gives the equivalent emission of the gas as carbon dioxide.'

where DC is the subscript for the category Dairy Cows. In addition, one can specify the source category Enteric Fermentation with the addition of the subscript EF .

$$CH_{4,\,DCEF,\,t} = f\left(q_{DCEF,t}, \alpha_{DCEF,t}\right) \tag{17}$$

Finally, this relationship can be expressed explicitly as

$$CH_{4,\,DCEF,\,t} = q_{DCEF,t} * \alpha_{DCEF,t} \tag{18}$$

where; $q_{DCEF,t}$ is the is the number of head of dairy cows in time t used in the calculation of emissions from enteric fermentation, $\alpha_{DCEF,t}$ is the emission factor associated with the dairy cow category in time t used in the calculation of emissions from enteric fermentation.

This specification is the same for all subcategories of cattle and total CH_4 from enteric fermentation from cattle is given by:

$$CH_{4,\,CCEF,\,t} = \sum q_{iEF,t} * \alpha_{iEF,t} \tag{19}$$

where i takes the value of the subscript for each respective cattle category. The totals for the other livestock categories are calculated in a similar fashion.

The other source category for methane is CH_4 from manure management practices. Emissions from the various manure management systems contribute approximately 20 percent of all CH_4 and 11 to 12 percent of total CO_2 equivalent emissions from the sector.

The general formula for the calculation of CH_4 given in (15) can be specified to calculate CH_4 due to manure management associated with a given livestock population by adding the appropriate subscripts, such as:

$$CH_{4,\,BCMM,\,t} = f\left(q_{BCMM,t}, \alpha_{BCMM,t}\right) \tag{20}$$

for the calculation of CH4 emissions due to manure management activities associated with beef cow populations. As with enteric fermentation, $q_{iMM,t}$ is the is the number of head in livestock category i in time t used in the calculation of emissions from manure management, and $\alpha_{iMM,t}$ is the emission factor associated with livestock category i in time t used in the calculation of emissions from manure management.

Here *BC* denotes the Beef Cows category as it does in

$$CH_{4,\,BCMM,t} = q_{BCMM,t} * \alpha_{BCMM,t} \tag{21}$$

, so

$$CH_{4,\,CCMM,t} = \sum q_{iMM,t} * \alpha_{iMM,t} \tag{22}$$

is just the total CH_4 for all cattle categories due to manure management. Of course, $\alpha_{iMM,t}$ will take real, non-negative values and *i* will take the subscript for each cattle category.

Calculations become more involved for the emissions of nitrous oxide (N_2O). Here is where non-livestock outputs have their effect, so crops and fertiliser projections begin to be used in addition to head of livestock. Furthermore, the calculations for the portion of N_2O attributed to manure management practices utilise different population figures and emission factors for each of the broad waste management systems, i.e. solid, liquid, and agricultural soils/unmanaged systems. A broad level discussion of the calculations for N_2O follows below.

Emissions from nitrous oxide may be classified into three source categories: solid waste management systems, liquid waste (i.e. slurry) management systems, and agricultural soils (unmanaged) systems. Each of these broad categories is in turn subdivided, so Figure I.1 is provided below for clarity.

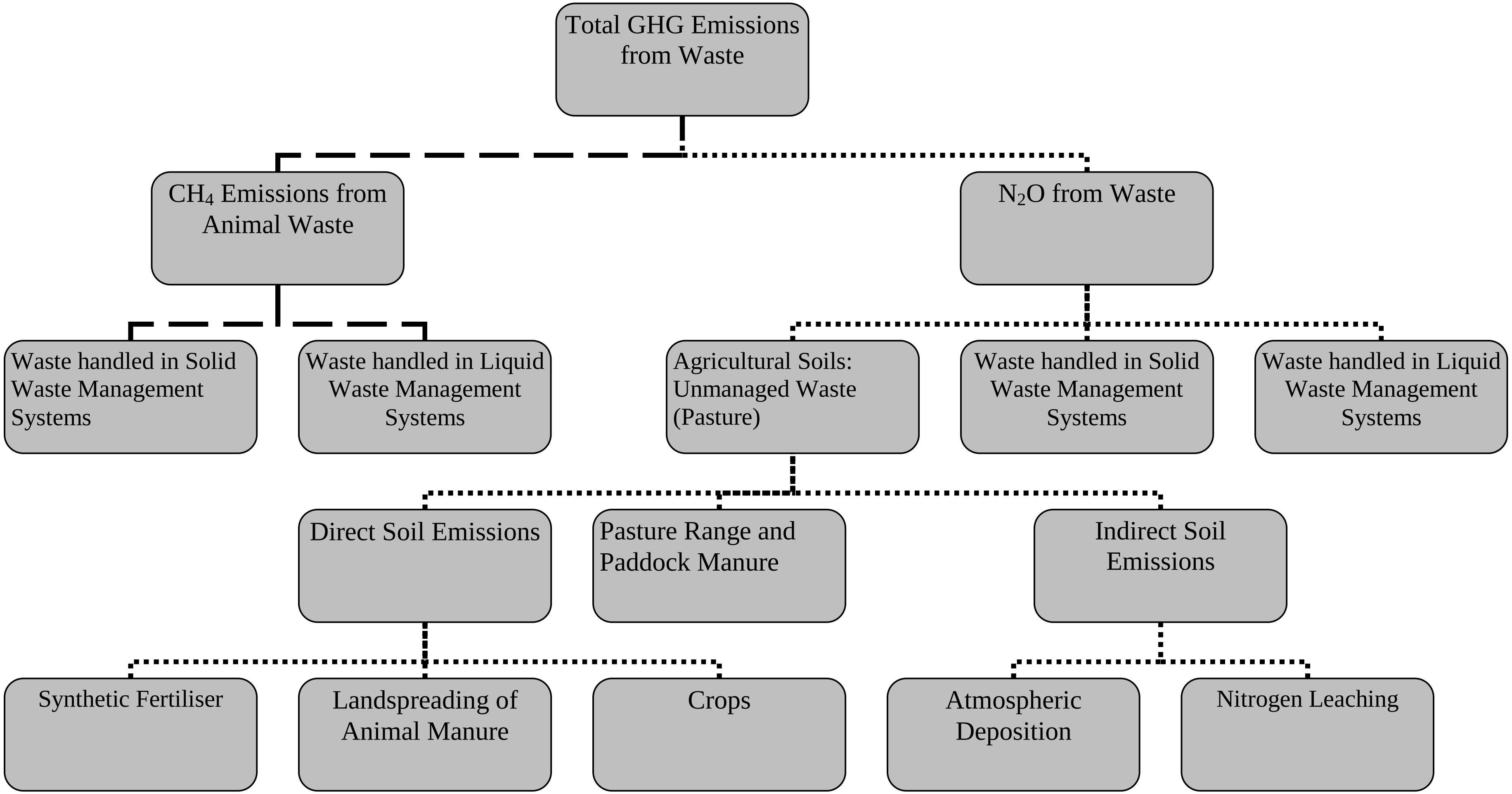
In the calculation of methane emissions, the general formula is given in (15), whereas the general form for the calculation of nitrous oxide is given below as

$$N_2O_{j,t} = f\left(q_{j,t}, \beta_j\right) \tag{23}$$

A key difference in the calculations of the two gases is that in (15) α_i can be considered a scalar in time t, but in (23) β_j is a vector.

There are multiple coefficients in the calculation of N_2O emissions in time t: excretion rates of animal manures, rates of volatilisation of N, a constant for the conversion rate of N_2O, as well as the relevant emission factor for the waste management system being considered. The agricultural soils subcategories also utilise various ratios. The reader will find detailed descriptions of all the source categories of GHG from agriculture in the EPA's GHG inventory documentation (EPA, 2009a).

Figure I.1. Structure of Emissions from Waste



Source: FAPRI – Ireland Agricultural Emissions Model

I.3 The Baseline-Scenario Method of Impact Analysis

Creating a Baseline – The Reference Scenario

The FAPRI-Ireland Agricultural Emissions model is well suited to impact assessments of the effects of a change in agricultural or trade policy, technological innovation, or changes in the macroeconomic outlook. The method of analysis involves creating a baseline scenario in which assumptions about future policy changes are kept to a minimum. This baseline is the yardstick by which the impact of the policy shock and other shocks are then measured. After the baseline is established, a scenario shock is run through the system, and the results are compared to the baseline. The difference between the shock scenario's outputs and the baseline scenario's outputs is the effect of the shock, *ceteris paribus*.

The typical approach for establishing a baseline is to exclude any policy which has not been agreed upon at the time the analysis is conducted. This typically means that policies known to be 'in the pipeline', but not yet agreed, are excluded from the baseline. However, due to the nature of subject matter and the requirements of the relevant stakeholders, the FAPRI-Ireland Agricultural Emissions model does include likely policy changes in its assumptions where necessary. To highlight this difference from the typical approach, we call our GHG baseline the 'reference scenario'.

Including Policy Targets - A more meaningful analysis

Performing an impact analysis involves asking these two fundamental questions: a) Where did we expect to be before the shock occurred?' and b) 'Where are we now that the shock has occurred?'. For impacts on projections, the second query may be amended to ask, 'Where do we expect to go now that the shock has occurred?'. Often, it is also instructive to compare projections with policy targets, and this is in effect asking, 'Where do we aim to go?'.

Regarding this last question, we considered the hypothetical situation that the agricultural sector will be obliged to reduce GHG emissions to a degree proportionate to the national target under the EU 20-20-20 agreement, and to that end we extrapolated a smooth reduction path over the 10 year projection period. Agricultural emissions would stand at 14.93 Mt, which is 20 percent lower relative to the 2005 level at the end of the projection period. However, this approach recognises the reality that such sweeping structural change invariably occurs incrementally over a number of years.

Including policy targets in this way gives a new dimension to the analysis. Now we can easily see what effect the shock is likely to have on the sector not only in terms of production and emissions, but also in terms of *policy*. For example, if a particular shock brings a sector more in line with policy goals, then a case can be made for measures which less aggressively pursue the target, or for a reduction in interventions altogether. Similar reasoning applies for instances when a shock pushes the sector further away from policy goals, or for when a shock has little or no effect.

Running a Shock – The Effect of the Global Recession on Irish Agricultural GHG Emissions

The normal maintenance of the model requires that the reference scenario be updated at least once a year when new macroeconomic and policy data become available. Ideally an additional year of observed historical data should also be added as part of an update and periodically equation re-estimation will need to take place. In years where large and unexpected changes have occurred, these updates can be modelled as shocks in and of themselves. The year 2009 will undoubtedly be remembered for its unforeseen and dramatic changes to the global economy. This makes this year's update particularly interesting to model as a macroeconomic shock.

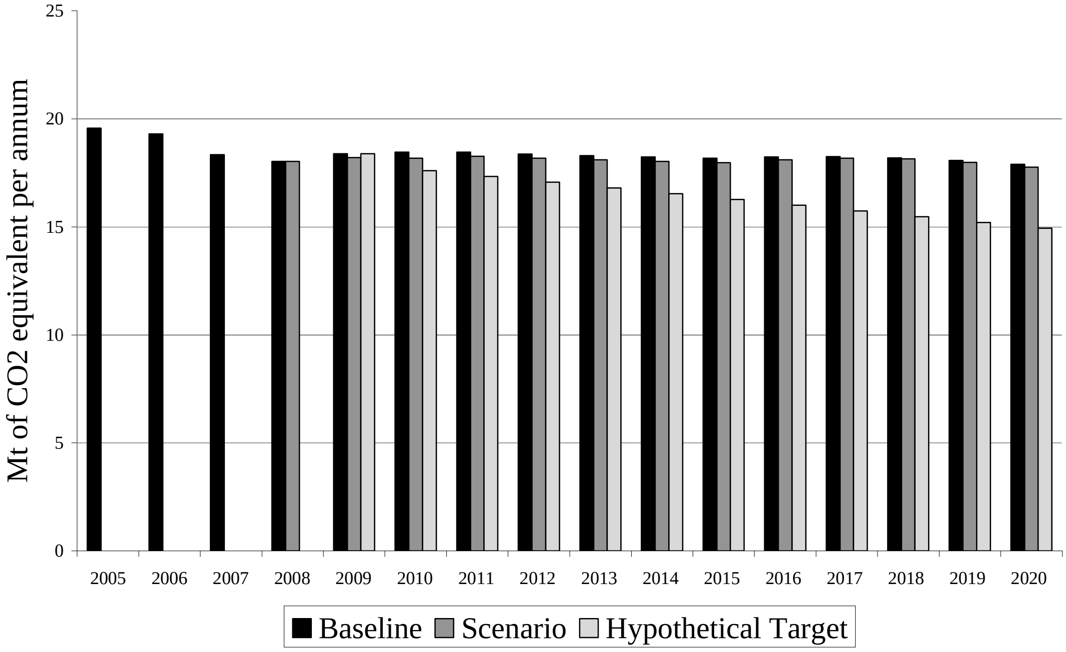
The model is updated primarily through a selection of exogenous prices which have an impact on domestic prices. Table I.5 in the Annex lists the key commodity prices which were to be updated and the reference values for those prices, whilst Table I.6 shows the updated scenario values.

I.4 Results and Discussion

The changes in the key commodity prices listed in Table I.5 will imply impacts in the production levels, and therefore in GHG emissions. Table I.2, Table I.3, and Table I.4 summarise the impact on emissions listed by the various gas and source categories.

The difference between the reference and updated scenario projections ranges from a peak of 0.276 Mt in 2010 to a low of 0.053 Mt by 2018. By the end of the projection period in 2020, the difference is 0.138 Mt, with the reference projection at 17.90 Mt and the scenario projection at 17.76.

Figure I.2. Projected GHG emissions from Agriculture



Source: FAPRI – Ireland Agricultural Emissions Model

Table I.2. Baseline emissions projections by gas and source category (Mt)

Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CH_4 from Fermentation	0.413	0.415	0.416	0.415	0.414	0.413	0.412	0.414	0.415	0.413	0.411	0.407
CH_4 from Manure	0.097	0.098	0.098	0.097	0.096	0.097	0.097	0.098	0.099	0.099	0.099	0.098
Total CH_4	**0.510**	**0.513**	**0.514**	**0.512**	**0.511**	**0.510**	**0.509**	**0.512**	**0.513**	**0.512**	**0.509**	**0.505**
CO_2 equivalent of CH_4	**10.708**	**10.769**	**10.790**	**10.752**	**10.724**	**10.704**	**10.683**	**10.745**	**10.777**	**10.757**	**10.695**	**10.603**
N_2O from Slurry System	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N_2O from Solid System	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N_2O from Pasture System	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Direct N_2O from fertiliser	0.007	0.007	0.007	0.007	0.007	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Direct N_2O from soils – FAW*	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Direct N_2O from Crops	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Direct N_2O -Crop Residue	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Indirect Emissions of N_2O	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N_2O from Leaching	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Total N_2O	**0.022**	**0.022**	**0.022**	**0.022**	**0.022**	**0.022**	**0.021**	**0.021**	**0.021**	**0.021**	**0.021**	**0.021**
CO_2 equivalent of N_2O	**6.831**	**6.833**	**6.814**	**6.771**	**6.729**	**6.679**	**6.641**	**6.635**	**6.621**	**6.584**	**6.523**	**6.448**
Total CO_2 equivalent	17.539	17.601	17.605	17.523	17.453	17.383	17.324	17.380	17.398	17.341	17.218	17.051
Fuel Combustion**	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850
Total CO_2 equivalent	**18.389**	**18.451**	**18.455**	**18.373**	**18.303**	**18.233**	**18.174**	**18.230**	**18.248**	**18.191**	**18.068**	**17.901**

*FAW - From Animal Waste

**Fuel Combustion data is sourced from Sustainable Energy Authority of Ireland. It is exogenous to the model , and is assumed constant throughout the projection period

Source: FAPRI – Ireland Agricultural Emissions Model

Table I.3. Scenario emissions projections by gas and source category (Mt)

Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CH_4 from Fermentation	0.412	0.413	0.414	0.413	0.413	0.412	0.411	0.416	0.419	0.419	0.416	0.411
CH_4 from Manure	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.098	0.098	0.098	0.098	0.097
Total CH_4	**0.508**	**0.510**	**0.511**	**0.510**	**0.510**	**0.509**	**0.508**	**0.514**	**0.517**	**0.518**	**0.514**	**0.509**
CO_2 equivalent of CH_4	**10.678**	**10.703**	**10.735**	**10.716**	**10.704**	**10.688**	**10.665**	**10.788**	**10.867**	**10.868**	**10.801**	**10.680**
N_2O from Slurry System	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N_2O from Solid System	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N_2O from Pasture System	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Direct N_2O from fertiliser	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Direct N_2O from soils – FAW*	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Direct N_2O from Crops	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Direct N_2O -Crop Residue	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Indirect Emissions of N_2O	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N_2O from Leaching	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002
Total N_2O	**0.022**	**0.021**	**0.022**	**0.021**	**0.021**	**0.021**	**0.021**	**0.021**	**0.021**	**0.021**	**0.020**	**0.020**
CO_2 equivalent of N_2O	**6.677**	**6.622**	**6.686**	**6.619**	**6.551**	**6.483**	**6.450**	**6.464**	**6.462**	**6.420**	**6.341**	**6.234**
Total CO_2 equivalent	17.354	17.325	17.421	17.335	17.255	17.171	17.115	17.252	17.330	17.288	17.142	16.914
Fuel Combustion	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850
Total CO_2 equivalent	**18.204**	**18.175**	**18.271**	**18.185**	**18.105**	**18.021**	**17.965**	**18.102**	**18.180**	**18.138**	**17.992**	**17.764**

*FAW - From Animal Waste

**Fuel Combustion data is sourced from Sustainable Energy Authority of Ireland. It is exogenous to the model , and is assumed constant throughout the projection period

Source: FAPRI – Ireland Agricultural Emissions Model

Table I.4. Difference from reference emissions projections by gas and source category (Mt)

Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
CH_4 from Fermentation	-0.001	-0.002	-0.002	-0.002	-0.002	-0.001	-0.001	0.002	0.005	0.006	0.006	0.005
CH_4 from Manure	0.000	-0.001	-0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001
Total CH_4	**-0.001**	**-0.003**	**-0.003**	**-0.002**	**-0.001**	**-0.001**	**-0.001**	**0.002**	**0.004**	**0.005**	**0.005**	**0.004**
CO_2 equivalent of CH_4	**-0.030**	**-0.066**	**-0.055**	**-0.036**	**-0.020**	**-0.017**	**-0.019**	**0.043**	**0.090**	**0.111**	**0.106**	**0.077**
N_2O from Slurry System	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N_2O from Solid System	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N_2O from Pasture System	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Direct N_2O from fertiliser	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001
Direct N_2O from soils – FAW*	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Direct N_2O from Crops	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Direct N_2O -Crop Residue	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Indirect Emissions of N_2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N_2O from Leaching	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total N_2O	**0.000**	**-0.001**	**0.000**	**0.000**	**-0.001**	**-0.001**	**-0.001**	**-0.001**	**-0.001**	**-0.001**	**-0.001**	**-0.001**
CO_2 equivalent of N_2O	**-0.154**	**-0.210**	**-0.129**	**-0.152**	**-0.177**	**-0.196**	**-0.191**	**-0.171**	**-0.159**	**-0.164**	**-0.182**	**-0.215**
Total CO_2 equivalent	-0.185	-0.276	-0.184	-0.188	-0.198	-0.212	-0.209	-0.127	-0.069	-0.053	-0.076	-0.138
Fuel Combustion	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total CO_2 equivalent	**-0.185**	**-0.276**	**-0.184**	**-0.188**	**-0.198**	**-0.212**	**-0.209**	**-0.127**	**-0.069**	**-0.053**	**-0.076**	**-0.138**

*FAW - From Animal Waste

**Fuel Combustion data is sourced from Sustainable Energy Authority of Ireland. It is exogenous to the model , and is assumed constant throughout the projection period

Source: FAPRI – Ireland Agricultural Emissions Model

Table I.5. Reference international commodity prices (€ per unit)

	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
European R3	333.45	314.50	307.59	316.26	323.78	328.27	330.96	333.36	335.11	335.78	336.74	337.47
European Lamb	442.44	429.31	420.26	425.62	431.91	434.97	435.94	437.05	437.79	438.15	439.49	440.84
European Pig	160.87	153.87	146.66	150.51	155.87	156.35	154.63	153.30	151.86	150.34	149.42	148.51
UK Pig	152.90	152.90	152.90	152.90	152.90	152.90	152.90	152.90	152.90	152.90	152.90	152.90
German Chicken	194.06	188.28	188.65	192.78	196.02	196.41	195.71	194.68	193.48	192.72	192.20	191.37
UK Barley	132.97	123.42	127.16	132.98	137.91	137.99	136.82	134.93	133.57	131.75	129.72	126.52
German Butter	309.04	300.72	300.82	301.91	301.78	300.99	299.86	299.65	298.15	296.38	294.81	292.51
French Cheese	453.64	442.03	448.79	455.94	461.14	463.75	464.19	465.55	465.50	465.10	465.44	465.65
Dutch S. Milk Powder	221.64	218.63	222.70	227.89	232.46	235.09	236.52	238.59	239.99	241.02	242.38	243.81
Whole Milk Powder	258.20	229.22	227.75	228.60	229.01	228.40	227.42	229.13	229.11	226.41	223.80	221.25
Rape meal, Hamburg	176.72	175.34	177.03	179.83	177.43	172.08	164.96	157.41	148.39	146.36	144.36	142.43
Sun meal, Rotterdam	180.93	175.59	178.99	183.77	185.29	183.05	178.04	172.75	163.40	161.15	158.95	156.83
Soy meal, Rotterdam	263.07	237.78	237.22	241.86	240.33	235.70	227.68	220.04	209.63	206.75	203.93	201.20

Rape meal, sun meal, soy meal, and barley are € per tonne. All else are € per 100 kg.

Source: FAPRI – Ireland Agricultural Emissions Model

Table I.6. Scenario international commodity prices (€ per unit)

	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
European R3	319.03	296.84	301.95	310.87	316.03	323.66	330.03	333.26	336.50	338.87	342.65	345.51
European Lamb	405.72	411.54	409.13	414.51	422.92	428.35	430.34	430.54	432.04	433.66	436.22	437.76
European Pig	143.97	138.97	143.03	147.25	147.17	147.88	148.83	148.59	148.18	147.60	147.10	146.55
UK Pig	158.61	143.82	148.17	152.76	152.97	153.57	154.42	154.14	153.67	153.04	152.49	151.90
German Chicken	203.42	188.69	185.46	187.56	188.97	189.00	188.74	187.88	186.94	185.86	184.85	183.90
UK Barley	76.12	91.21	89.97	89.90	90.28	90.95	90.89	89.96	89.14	88.22	86.95	85.54
German Butter	278.27	206.02	199.68	194.04	192.69	192.91	192.26	191.82	191.18	190.64	189.79	189.20
French Cheese	358.71	337.67	367.04	365.81	369.93	374.16	374.63	374.72	374.29	373.68	372.24	371.89
Dutch S. Milk Powder	164.87	224.71	207.61	202.63	207.83	212.11	213.92	215.72	216.75	217.28	216.39	216.27
Whole Milk Powder	186.24	216.34	205.21	198.53	202.44	207.33	212.48	216.97	219.54	220.57	217.83	216.06
Rape meal, Hamburg	158.53	135.54	129.72	129.76	131.52	132.44	132.52	131.03	129.31	127.36	125.73	124.68
Sun meal, Rotterdam	140.52	138.77	132.03	130.70	130.18	129.79	127.27	122.85	118.43	114.01	112.55	111.61
Soy meal, Rotterdam	281.04	234.19	227.60	229.17	231.70	233.45	232.62	228.85	225.10	221.73	218.90	217.07

Rape meal, sun meal, soy meal, and barley are € per tonne. All else are € per 100 kg.

Source: FAPRI – Ireland Agricultural Emissions Model

Table I.7. Change in international commodity prices (€ per unit)

	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
European R3	-14.42	-17.66	-5.64	-5.39	-7.75	-4.61	-0.93	-0.10	1.39	3.09	5.91	8.04
European Lamb	-36.72	-17.77	-11.13	-11.11	-8.99	-6.62	-5.60	-6.51	-5.75	-4.49	-3.27	-3.08
European Pig	-16.90	-14.90	-3.63	-3.26	-8.70	-8.47	-5.80	-4.71	-3.68	-2.74	-2.32	-1.96
UK Pig	5.71	-9.08	-4.73	-0.14	0.07	0.67	1.52	1.24	0.77	0.14	-0.41	-1.00
German Chicken	9.36	0.41	-3.19	-5.22	-7.05	-7.41	-6.97	-6.80	-6.54	-6.86	-7.35	-7.47
UK Barley	-56.85	-32.21	-37.19	-43.08	-47.63	-47.04	-45.93	-44.97	-44.43	-43.53	-42.77	-40.98
German Butter	-30.77	-94.70	-101.14	-107.87	-109.09	-108.08	-107.60	-107.83	-106.97	-105.74	-105.02	-103.31
French Cheese	-94.93	-104.36	-81.75	-90.13	-91.21	-89.59	-89.56	-90.83	-91.21	-91.42	-93.20	-93.76
Dutch S. Milk Powder	-56.77	6.08	-15.09	-25.26	-24.63	-22.98	-22.60	-22.87	-23.24	-23.74	-25.99	-27.54
Whole Milk Powder	-71.96	-12.88	-22.54	-30.07	-26.57	-21.07	-14.94	-12.16	-9.57	-5.84	-5.97	-5.19
Rape meal, Hamburg	-18.19	-39.80	-47.31	-50.07	-45.91	-39.64	-32.44	-26.38	-19.08	-19.00	-18.63	-17.75
Sun meal, Rotterdam	-40.41	-36.82	-46.96	-53.07	-55.11	-53.26	-50.77	-49.90	-44.97	-47.14	-46.40	-45.22
Soy meal, Rotterdam	17.97	-3.59	-9.62	-12.69	-8.63	-2.25	4.94	8.81	15.47	14.98	14.97	15.87

Rape meal, sun meal, soy meal, and barley are € per tonne. All else are € per 100 kg.

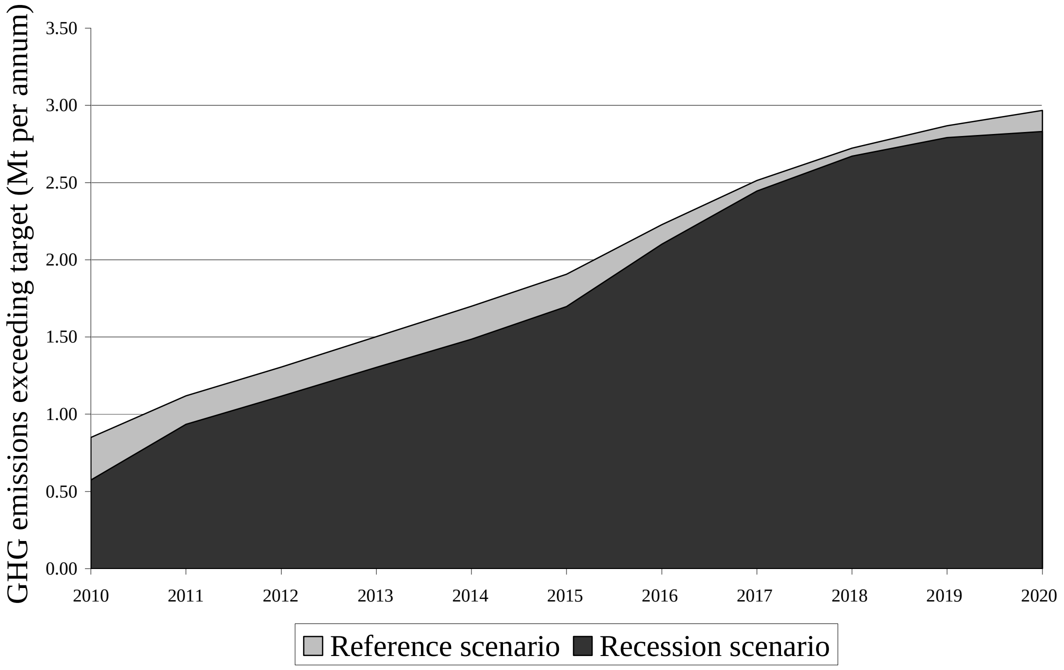
Source: FAPRI – Ireland Agricultural Emissions Model

Figure I.2 above shows the reference scenario emissions path alongside the updated recession scenario and hypothetical reduction target emissions paths. The effect of the recession scenario is to bring emissions closer to the target, but by only a marginal amount.

Figure I.3 shows the amount by which emissions of GHG overrun targets in each year in the projection period. As can be seen in this figure, the scenario projection's emissions exceed the hypothetical yearly targets by slightly less than the reference scenario's projected emissions levels. However, both the reference and the recession scenarios show overages which are increasing throughout the projection period.

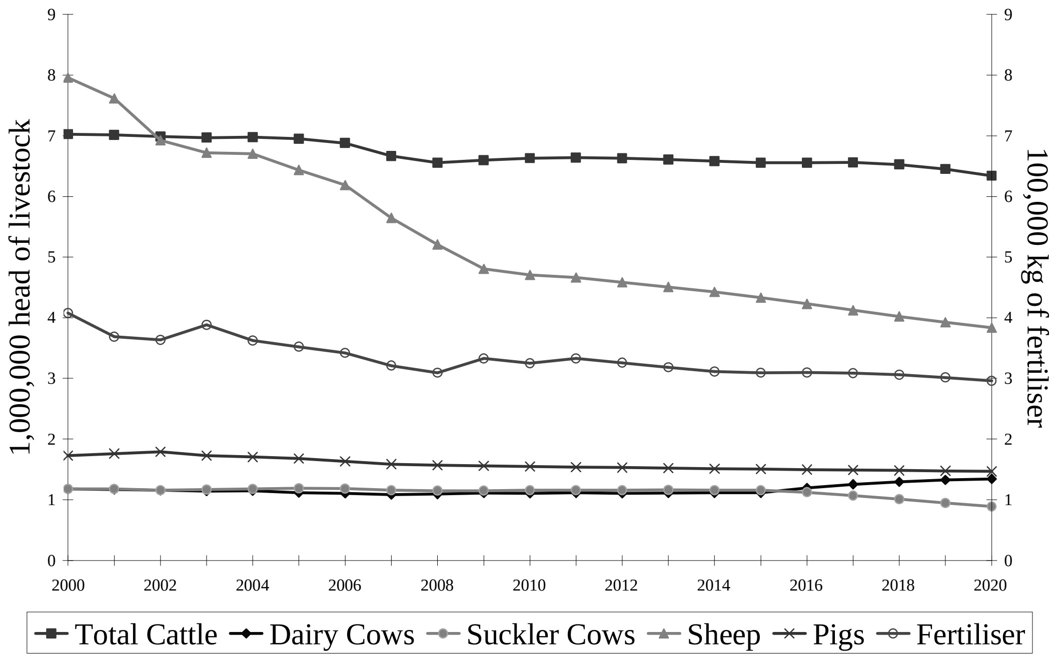
The population and fertiliser usage levels which are underlying the GHG projections are depicted in Figure I.4 with historical data dating back to 2000. The greater emphasis on dairy production and attendant decline in specialist beef production post quota abolition in 2015 is evidenced by the divergence between the beef and dairy cow series at the end of the projection period. Fertiliser usage falls slowly, and sheep numbers more quickly with both following established long term trends. Pig numbers change very little, and crucially total cattle remain relatively constant throughout.

Figure I.3. Emissions exceeding targets to 2020



Source: FAPRI – Ireland Agricultural Emissions Model

Figure I.4. Projected livestock populations and fertiliser usage



Source: FAPRI – Ireland Agricultural Emissions Model

I.5 Conclusion

According to the International Monetary Fund's (IMF) World Economic Outlook, the global recession of 2009 was 'the deepest post–World War II recession by far. Moreover, the downturn is truly global: output per capita is projected to decline in countries representing three-quarters of the global economy' (IMF, 2009, Foreword, p. xii). Its effects in Ireland have also been profound, yet this analysis finds that the impact on GHG emissions from Irish agriculture is likely to be muted.

The relatively small changes in projected international commodity prices are indicative of a small impact on international agricultural markets. With Irish agriculture being export focussed, these are the price signals which truly matter for domestic production decisions. This being the case, it is not surprising that there are no large changes in the projections for bovine populations.

It is the steadfastness of the bovine population projections which are the main cause of the lack of responsiveness in GHG emissions. With bovine populations being the primary driver of emissions from the sector no large changes in GHG emissions projections should be expected under these circumstances.

One major source of N_2O in the model is the use of synthetic fertilisers. However, with the majority of agricultural land under grassland, and most of this land being associated with bovine production systems, the usage of synthetic fertilisers is also closely tied to the size of the national herd.

These results highlight the difficulties of reducing overall emissions in an agricultural sector which is based on the production and export of dairy and beef products.

Despite the adverse economic conditions which farmers have had to face in the past year the model shows an agricultural sector which only barely deviates from its medium term emissions path. In the absence of a transformational technological innovation, additional emissions abatement may only come at the price of smaller livestock populations. However, increased productivity may mitigate or wholly avoid losses in output and reduce emissions on a per unit basis.

References

Environmental Protection Agency (2009a). *Ireland's Greenhouse Gas Emission in 2007: Greenhouse Gas Emissions 1990 - 2007 Reported to the United Nations Framework Convention on Climate Change*. County Wexford, Ireland.

Environmental Protection Agency (2009b). National Inventory Report 2009. County Wexford, Ireland.

Environmental Protection Agency (2010a). Ireland’s Greenhouse Gas Emissions in 2008. 15th April, 2010. County Wexford, Ireland.

Environmental Protection Agency (2010b). Ireland’s Greenhouse Gas Emissions Projections 2010-2020. April 28th, 2010. County Wexford, Ireland.

European Environment Agency (2009). Annual European Community Greenhouse Gas Inventory 1990 - 2007 and Inventory Report 2009: Submission to the UNFCCC Secretariat. 27 May 2009. Copenhagen.

Eurostat (2010). Cattle population (annual data) - Cows. Data Series Code: apro_mt_lscatl. *http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database* Accessed: 17th May, 2010

Hanrahan, K. (2001). The EU GOLD Model 2.1: An Introductory Manual. Dublin.

International Monetary Fund (2009). *World Economic Outlook: Crisis and Recovery*, World Economic and Financial Surveys. April, 2009. Washington, D.C., USA.

IPCC (2007). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Core Writing Team, R. K. Pachauri and A. Reisinger. Geneva, Switzerland**:** 104.

IUCC (Information Unit on Climate Change) (1998). The Kyoto Protocol to the Framework Convention on Climate Change. Geneva, Switzerland.

Lanzieri, G. (2008). *First demographic estimates for 2008.* 49/2008. Data in Focus: Population and social conditions. 15.12.2008 Eurostat. Catalogue number: KS-QA-08-049-EN-N. ISSN: 1977-0340. [online]: http://epp.eurostat.ec.europa.eu Date Accessed: 19 January 2010

DECISION No 406/2009/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020