

Controlling Greenhouse Gas Emissions from the Agricultural Sector in Ireland: A CGE Modeling approach

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Abstract: A disaggregated Computable General Equilibrium (CGE) Model of the Irish economy is used to analyse the effects of agricultural policy change on greenhouse gas emissions from the Irish agricultural and forestry sectors. The simulations find that the adoption of the EU Common Agricultural Policy (CAP) Mid-Term Review proposals would enable Ireland to meet its greenhouse gas emission target for the agricultural sector.

Key words: CGE Model, Agricultural policy, Greenhouse gas emissions

1. Introduction

Ireland is unique among the EU15 countries for the proportion of its greenhouse gas (GHG) emissions which originate in agriculture. This reflects the predominantly pastoral nature of Irish agriculture, in which livestock and livestock products account for around 87 per cent of total agricultural output. In 1990, the base year for the Kyoto Protocol, agriculture was Ireland's single largest producer of GHG emissions, accounting for 35 per cent of the total (Department of the Environment, 2000). If Ireland is to achieve its target under the Kyoto Protocol and the EU Burden Sharing Agreement, reducing GHG emissions from agriculture must be a key part of the strategy.

Reducing GHG emissions from agriculture could be tackled through specific climate change policy measures. However, agricultural production is also strongly influenced and regulated by the support mechanisms of the EU's Common Agricultural Policy (CAP). These mechanisms include market price support for the main commodities (underpinned by import tariffs, export subsidies and intervention buying) and direct payments. The latter play an increasingly important role in supporting Irish agricultural incomes, accounting for 69 per cent of operating surplus in 2002 (Department of Agriculture and Food, 2003).

In July 2002 the EU Commissioner for Agriculture and Rural Development, Dr Fischler, proposed a further reform of EU agricultural support mechanisms as part of the Mid-Term Review (MTR) of the Agenda 2000 reform package agreed in 1999 (Commission, 2002). These proposals were elaborated in a revised document released in January 2003 (Commission, 2003a). Two key elements of the MTR are a proposal to decouple direct payments to farmers from any requirement to produce particular crops or livestock in order to retain eligibility for receipt of these payments, plus a further reform of the arable and dairy market regimes using the MacSharry/Agenda 2000 formula of reducing intervention price support while partially compensating farmers for the resulting income loss through increased direct payments. Impact studies carried out for the Commission and by INEA for the EU as a whole (Commission, 2003b and 2003c, Conforti et al., 2002), as well as an impact study of the decoupling proposal only for Irish agriculture using the FAPRI-Ireland model (Teagasc, 2003), indicate that these proposals will result in a reduced level of agricultural production.

As a corollary of this effect, GHG emissions from agriculture will also be reduced. Teagasc (2003) calculate the GHG consequences for Ireland using the FAPRI-Ireland partial equilibrium (PE) agricultural sector model which incorporates forestry as an alternative land use. The model is used to project the levels of output of the main commodities, as well as the use of synthetic nitrogen, under alternative policy scenarios. The emissions effect of these alternative scenarios is then calculated using established emissions coefficients. They conclude that the expected reduction in GHG emissions would more than meet the targets set for the agricultural sector in the Irish government's climate change strategy if the MTR decoupling proposals were adopted as proposed.

This paper presents changes in GHG emissions and economic results from a simulation of the decoupling and market regime proposals for change in the

Commission's January 2003 version of the MTR proposals using a computable general equilibrium model of the Irish economy with a disaggregated agri-food sector, the Irish Model of Agriculture, General Equilibrium (IMAGE). Part of the motivation for the paper is to explicitly compare the outcomes from running the same simulation using both a partial and general equilibrium model of Irish agriculture. The FAPRI-Ireland model provides much more disaggregated results at the sectoral level (Teagasc, 2003). However, it does not capture linkage effects with the rest of the economy via the markets for primary factors, intermediate inputs and the foreign balance. A second motivation is to contribute to the debate on the appropriate modelling of CAP policies in CGE models. Anania (2001) has criticised the stylised representation of CAP policies in previous modelling attempts and has called for more explicit modelling of CAP policy instruments. As IMAGE is a national and not a multi-regional model, many of his specific criticisms of the way CAP market and trade policies, such as discriminatory trade preferences or quantitative limits on export subsidies, are incorporated into CGE models are not relevant; IMAGE simulations require exogenous information (generated either from global models or from industry experts) of the likely exogenous shocks for Irish agriculture arising from EU-wide commitments. However, we model decoupling in a somewhat different manner to that used by Conforti et al. (2002) in their CGE MTR analysis. Other features of the model in the direction of greater realism are the modelling of joint production of beef and milk (important in the Irish context where over 50 per cent of beef output originates from the dairy herd), distinguishing between different land classes to constrain unrealistic land use changes, and the inclusion of the dairy quota regime.

Section 2 of the paper discusses GHG emissions from Irish agriculture, and the strategies and targets for the sector. Section 3 briefly describes the main features of IMAGE, a CGE model of the Irish economy. The section highlights the modelling of CAP instruments in the model. Section 4 discusses the simulation shocks and Section 5 presents the results of the simulations. Conclusions and reflections on further work are contained in Section 6, and tables and figures are contained in Appendix 1.

2. Irish Agriculture and the Greenhouse Effect

In the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) (UN, 1997), developed countries agreed to reduce annual emissions of GHGs by 5% on 1990 levels by the commitment period 2008 – 2012. Under the EU agreement to share the burden of this reduction between its Member States, Ireland's target is to limit the increase in emissions to 13 per cent. However, Ireland's rapid economic growth during the 1990s (averaging 8 per cent GDP growth between 1995 and 2002) means that the business as usual forecast is that emissions will increase by 37 per cent during the commitment period (DoE, 2000). Emissions in 2000 were 24 per cent above 1990 levels (EEA, 2002), therefore Ireland must now achieve reductions in GHG emissions during this decade.

Ireland's high proportion of agricultural GHG emissions arises because of the dominance of ruminant livestock production in Irish agricultural output, and the high global warming potential (GWP) of the associated emissions. Enteric fermentation, the process of ruminant digestion, produces Methane, which has 21 times the GWP of carbon dioxide per weight. The management of the associated manure also produces

methane, and along with the use of soil fertilisers in pasture and crop production, produces nitrous oxide, with GWP of 310 times carbon dioxide per weight.

The National Climate Change Strategy (NCCS) (DoE, 2000) proposes a range of measures to reduce GHG emissions from the agricultural sector by 2.41Mt CO₂ equivalent per annum. The reduction targets are shown in Table 1. These targets appear to be based on industry opinion as to what might be feasible rather than any formal modelling of least-cost strategies to remain within the overall commitment levels for Ireland.

The contribution expected from on-farm forestry sequestration arises from the afforestation of 70,000 hectares of land which is currently in agriculture, or an increase of forest cover of around 11%. With only 9% of land covered by forest, Ireland is one of the least afforested countries in Europe (DoE, 2000). As forestry acts as a sink through the sequestration of carbon dioxide, changes in land use potentially could play an important role in helping Ireland to meet its commitment to the Kyoto Protocol. The Irish government put forward an afforestation programme in 1996 (Department of Agriculture, Food and Forestry, 1996) which set national planting targets of 20,000 hectares per annum for the period 2001-2030. After a promising start, actual planting levels have fallen since then to little more than half this target.

The sources of GHG reductions can be broadly categorised into an output effect and a technology effect. The output effect occurs when a reduction of output leads to a reduction in associated emissions. For example, the objective to reduce livestock numbers will lead to reduced output and emissions. The technology effect occurs when emission reduction strategies are output neutral, such as the reductions brought about by changed feeding regimes for cattle, lower fertiliser use, and improved manure management. Hence the Irish strategy appears to suggest that the output effect contributes to 31% of the reduction target. Whilst an individual country may achieve its target via both effects, the output effect will only lead to a reduction in global emissions if it is accompanied by a fall in demand, so that production does not shift elsewhere.

3. Methodology – the IMAGE model

The IMAGE model is based on the widely known ORANI model (Dixon et al. 1980) of the Australian economy that has been used extensively for policy analysis in Australia for nearly two decades. The model has a theoretical structure that is typical of many CGE models. It is a static model, as it does not have any mechanism for the accumulation of capital. This version of the model assumes perfect competition in all markets, with no individual buyer or seller being able to influence price. Demand and supply equations are derived from the solution of optimisation problems (e.g. profit or utility maximization) for private sector agents. The model allows for multiple household types, export destinations, land types and labour occupations. It also incorporates an explicit treatment of government revenue and expenditure. For further details see O'Toole and Matthews (2002a) and O'Toole and Matthews (2002b). The model is solved using the GEMPACK software (Harrison and Pearson 1996).

The model distinguishes 34 industries, the first eight of which relate to farm level production, making it the most disaggregated CGE model for Ireland thus far. There are two sources of commodities, namely domestic and overseas. The industry classification is listed in Appendix 2. The model allows every industry to produce several commodities by using domestic or imported intermediates and a primary factor composite consisting of land, labour and capital. This would suggest a potentially very large and complex system that would be extremely difficult to calibrate. To keep the model to a manageable size, we assume, firstly, that each industry with the exception of the dairy industry produces only one good and secondly, that input-output separability holds.

The dairy industry jointly produces milk for processing and cattle in the form of calves and cull cows. To reflect this, the Make matrix is amended to allocate a portion of the cattle industries output to the dairy industry based on an estimate of the value of cull cows and calves at birth. Any further rearing of the calves, even if carried out on dairy farms, is assumed to be part of the cattle industry. An equivalent portion of the costs of the beef industry is applied to the dairy industry in respect of the additional output on a pro-rata basis. As the model now incorporates a flow of calves from the dairy industry to the cattle industry as an intermediate input, a corresponding flow of calves which are used on cattle farms to produce cattle is also included. This requires no adjustment to costs as this flow of calves is simultaneously an additional sale and purchase by the cattle industry. However the Make matrix must be adjusted to the higher output level. Finally, the transformation elasticity, which specifies how easily a dairy farmer can shift production between milk and cattle as relative prices change is set at zero. This implies that milk and cattle from dairy farms are always produced in fixed proportions, and that it is not possible to increase/decrease one without increasing/decreasing the other.

The production structure used is detailed in Figure 1. At the top level of the nest the volume employed of each of the n intermediate inputs and the primary factor composite by each firm is assumed to be in a constant proportion. Each of the intermediate goods is the product of a hypothesised 'mixing' industry characterised by a CES function which combines the imports and domestic production of good i . The primary factor composite is formed through a combination of land, labour and capital. Household consumption is based on a Stone-Geary utility function, which leads to a linear expenditure system. Household consumption is divided into two components, a minimum or subsistence amount and a luxury amount. Each of the three households choose combinations of each consumption good to minimise a CES function.

The database for the model is a social accounting matrix for the Irish economy. The original source for the input-output data required is the CSO input-output tables for the Irish economy for 1993 extended to a social accounting matrix (SAM) showing the flows to institutions in the economy using the CSO National Income Accounts for 1993 and other sources (for details, see O'Toole and Matthews, 2002a). Agricultural industries are included on a 'national farm' basis, that is, intra-sectoral sales are netted out. This 1993 SAM was then updated to 1998 using published CSO data on the row and column totals (household and government expenditure, imports and exports, industrial production by sector, etc.). Finally, the 1998 SAM was projected forward to 2001 using the ESRI medium term review forecasts contained in Duffy et al. (1999).

An important feature of the model is the distinction between three categories of land used by the land-use sectors, agriculture and forestry. High and low quality agricultural land are both used in the production of all agricultural commodities, whereas low quality agricultural land is only used in the production of livestock. Some low quality agricultural land is also used in the forestry sector, along with non-agricultural land. In the original database, direct payments are divided into those which are paid as output subsidies (such as deseasonalisation premium on cattle) and other payments which are treated as input subsidies to land. The latter type of subsidies are removed in the decoupling scenarios. A third category of direct payments include compensatory payments to farmers in less-favoured areas, and agri-environment payments which are also treated as land subsidies (to land outside the high quality agricultural class) but which are not affected by the decoupling proposals. Land use and the subsidies removed under decoupling are shown in Table 2.

In other CGE models arable aid payments are treated as land subsidies but livestock payments are treated as subsidies to capital. Our treatment of livestock payments is justified because, while EU payments are headage payments which relate to the number of animals a farmer has, they are also tied to minimum stocking rates per acre, which means that they are in effect subsidies to land.

The dairy quota is modelled using Bach and Pearson's (1996) method for representing a kinked supply curve in GTAP. This method successfully captures the behaviour of producers when the quota changes status from binding to non-binding. The key parameter in the quota modelling is the shadow price of milk, which is set at 51% of the producers' price, following Consortium INRA – University of Wageningen (2002).

The greenhouse gas coefficients used were established by Behan (2003) using data from the Irish Department of Environment. The coefficients are given as emissions per unit of input, for example, methane emissions per dairy cow per year. IMAGE gives results in terms of percentage changes in price and quantity. Therefore we assume that a one per cent decrease in the volume of beef output gives a one per cent decrease in the number of beef cows, and a corresponding decrease in GHG emissions from enteric fermentation, manure management, and agricultural soil emissions associated with beef production. Technology changes to bring about GHG emission reductions have not been modelled as the purpose is to evaluate the contribution of agricultural policy changes affecting output and land use.

The main source of agricultural GHG emissions is enteric fermentation, responsible for 52% of emissions. Manure management is responsible for a further 11% of emissions. These sources of emissions are linked directly to the relevant livestock sectors. The remaining 37% of emissions are released from agricultural soils. In particular, the use of synthetic fertiliser in both livestock and crop production accounts for 50% of soil emissions. The emissions from this source have been allocated to each agricultural industry using fertiliser application rates from the FAPRI-Ireland model (Teagasc 2003). The remaining soils emissions are from manure based fertilisers which are assumed to be linked to the production of the relevant livestock. Sources of agricultural GHG emissions by sector are shown in Table 3.

In the base period for the model, there is no agricultural land used for forestry, by definition. However, one of the aims of the NCCS is to reduce emissions by on-farm forestry sequestration. The NCCS aims to convert 70,000 ha of agricultural land into forestry use, which would imply an increase in the total forestry area of approximately 11%. The expected sequestration from this is 0.25Mt CO₂ equivalent. Hence the (negative) emissions coefficient for new forestry has been calculated such that an 11% increase in forest output will result in sequestration of 0.25Mt CO₂ equivalent. This method of calculating the coefficient ensures that the model results are appropriate for the initial afforestation of agricultural land with young trees which have lower sequestration potential than mature trees. We find that 18kg of CO₂ are sequestered for a one euro increase in output.

Changes in agricultural output in a CGE model will have an impact on the composition of output in the non-agricultural sectors of the economy. In particular, it could lead to a change in fuel use in the economy arising from a change in the composition of output. Changes in fuel use would have a further impact (either positive or negative) on GHG emissions arising from agricultural policy reform. This effect was incorporated in the model output by relating the changes in use of the two energy inputs distinguished in the model, Petrol and Coal, and Electricity and Gas, to the GHG emissions from these energy sources. For the simulations reported here, these changes are very small.

4. Model shocks and closure

The simulations are intended to indicate the contribution which agricultural policy reform might make in assisting Ireland to meet its Kyoto Protocol targets. We have simulated two of the main elements of the MTR proposals of January 2003, namely, decoupling and the reform of the dairy market regime.¹ In addition, two further experiments were run using alternative definitions of decoupling to that put forward in the MTR. The shocks are defined as follows.

Decoupling. Decoupling is assumed to affect payments to cattle, sheep and cereals. Three versions of decoupling are modelled in the paper. In all cases, decoupled payments are modelled by removing the input subsidy on land, to simulate farm decision-making in an undistorted market. The decoupled payment is then simply modelled as a transfer to farm households. The degree of decoupling of the policy in practice is then reflected in the choice of closure indicating how free factors of production are to move around.

In the first version of decoupling, which we refer to as *intermediate* decoupling and which intended to simulate the MTR proposal, eligibility for payments depends on farmers remaining in farming although the payments are no longer linked to particular commodity outputs. The second version, *full decoupling*, is the more theoretically consistent notion of decoupling where the payments are made to farmers regardless

¹ It would also be possible to incorporate the dynamic modulation of direct payments as was done in Conforti et al. as a reduction in the decoupled payments. However, the principal impact of this would be on the income situation of farm households rather than on output levels, assuming the payments are decoupled, and thus this aspect of the MTR proposals was not explicitly included.

whether they remain in farming or not. The difference between the two simulations concerns the alternative uses of agricultural land; in the former case, it must remain within agriculture, although not necessarily in the same agricultural sector, while in the latter case, it can be used for the non-agricultural land-using activity of forestry.

Both of these approaches assume that all land remains in use, i.e. a full employment of land assumption. Under full decoupling, and without any obligation to maintain land in good agricultural use, it is possible that land would actually be retired from production completely, reverting to scrub or fallow. The implications of this are modelled in the third approach, called *partial decoupling*, where we assume that land may go out of production if the return to land falls by 20%. This might be justified on the grounds that farmers value the option of investing in forestry at a later date but not immediately (Wiemers and Behan, 2003). The 20% value has been arbitrarily chosen as a modelling device to relax the full employment of land assumption, and the results of this simulation should be treated as illustrative rather than relating to any specific policy scenario.

Dairy regime changes. In the dairy sector we assume the continuation of the dairy quota and model a reduction of 28% in the support price for milk products accompanied by a decoupled, partially compensating payment. Ireland is a small, open economy, therefore the reduction in price support is simulated by an exogenous fall in export demand by non-EU countries. That is, the policy makers behave like third countries when they enter the market at the intervention price and buy excess supply. Therefore if they wish to change the intervention price, this can be reflected by an exogenous shift in the export demand curve.

Model closure. A standard medium run closure is used, where labour within each occupation is assumed mobile within the economy, with aggregate supply of each labour type being determined by a function relating to unemployment within that occupation. The aggregate supply of land of each type (except in the partial decoupling scenario) is assumed fixed. Aggregate capital in agriculture, in manufacturing and in services respectively is assumed fixed, though mobile between uses within each category. Finally, the balance of trade is assumed fixed.²

5. Results

Selected simulation results are shown in Tables 4, 5, and 6.

Simulation 1: Intermediate Decoupling

The removal of the land subsidy simultaneously increases the cost of land to farmers, and decreases the return on land to landlords. In the Cattle and Cereals industries, the net effect is an increase in the cost of land, however, in other industries, including the Sheep industry, the net effect is a decrease in the cost of land, despite the removal of the subsidy. In particular, the Sheep industry, with relatively low subsidies (39%), is

² An alternative closure rule might be to hold the balance on current account fixed, allowing for changes in unrequited transfers such as CAP payments. However, the decoupling scenarios specifically assume that total expenditure by the EU on these payments in Ireland remains unchanged under each decoupling scenario.

able to increase its use of high quality land, which was initially heavily subsidised for the Cattle and Cereals industries (83% and 80% respectively). Although the removal of coupled payments to sheep production raises the cost of land, it is outweighed by the effect of decoupling payments in other land-using enterprises. This is an important illustration of a general equilibrium effect. If agricultural land is assumed to remain fully employed in agriculture, then land released from beef and cereals production must be used in some other agricultural enterprise. Further, because land must remain in agriculture, forestry is unable to bid land away from agriculture.

The change in costs facing the agricultural industries results in Cattle production falling by 17% and Cereals by 18%, whilst Sheep production increases by 19%. The dairy industry also benefits from the reduced cost of land, and despite the fall in the intervention price, the milk quota remains binding. However, the value of quota rent in the milk industry falls by 13%.

Beef cattle produce 59% of agricultural GHG emissions. On its own, the decrease in output of cattle results in a decrease in agricultural GHG emissions of 11%. Dairy cattle are the other significant producer of emissions, accounting for 25% of agricultural GHG emissions. Due to the quota, there is very little change in emissions from this source. The increase in other agricultural output, particularly sheep, results in a small increase in GHG emissions from other agricultural sectors, except the cereals sector. The net effect of the decoupling of payments is that agricultural GHG emissions fall by 9%. The changes in agricultural policy have a negligible effect on overall fuel usage in the economy. Hence we find that the decrease in total Irish GHG emissions is 2.7%.

Simulation 2: Full Decoupling

The results from this Simulation 2 are quite similar to the results from Simulation 1. The key difference is that agricultural land is not constrained to remain in agriculture. The forestry industry is able to capitalise on the reduced cost of land, such that the total output of forestry increases by 11%. Compared to Simulation 1, the decrease in agricultural production is slightly greater in the beef and cereals sectors, and the increase is slightly less in the sheep sector, at 18%.

The policy of full decoupling yields better results for GHG emission reductions, because land is removed from agriculture, an activity which produces emissions, into forestry, which reduces net emissions via carbon sequestration. As for Simulation 1, the main contributor to the reduction in agricultural GHG emissions is the beef sector which, on its own, causes a reduction of 11%. A further 1.6% of emissions are sequestered due to the increase in forestry. Again, the changes in agricultural policy have a negligible effect on overall fuel usage in the economy. The total reduction in agricultural GHG emissions is 11%, and the reduction in Irish GHG emissions is 3.2%.

Simulation 3: Partial Decoupling, where land may be idled

The results from Simulations 1 and 2 are based on the full employment of land. In those simulations, the returns on high and medium quality land fell by 55% and 50% respectively. In this simulation, to analyse the possibility that agricultural land may be left idle, we restrict the fall in returns to high and medium quality land to just 20%.

The results from this simulation are markedly different, with aggregate land use falling by 20%. The restriction on returns to land mean that the increase in the price of land to the beef, sheep, and cereals industries is greater than it was in Simulations 1 and 2. Now, output in all three of these sectors is reduced. The forestry sector is unable to reap the benefits of the relatively large fall in land prices from Simulation 2, however, it is still able to increase its usage of land, and output increases by 2%.

The sharp reduction in activity is accompanied by a large fall in agricultural GHG emissions, of 23%. Again, the reduction in cattle output is the main contributor to this fall. The reduction in activity also has the effect of reducing the usage of petrol and coal by 1%, and electricity and gas by 0.5%. The total reduction in GHG emissions for Ireland is 6.9% under this scenario.

6. Conclusions

Decoupling will lead to a reduction in agricultural GHG emissions, mainly by reducing the attractiveness of beef farming, the major contributor to agricultural GHG emissions. The policy details are crucial in determining the level of reductions. In particular, if agricultural land is allowed to be transferred to forestry, we reap a double dividend, because land is no longer in emission producing activities, and it is instead used in emission sequestration. Total land-use emissions fall by 11%, compared to a fall of 9% when land is constrained to remain in agriculture. Our third simulation demonstrates that further reductions in emissions would be achieved if a *de facto* price floor exists for land rental, as this would result in land being removed from productive use.

Our results may be sensitive to the precise relationship between the size of the land subsidy implied by the existing flow of coupled direct payments and the imputed rental return to land. The rental return to land is an imputed figure and there are different possible methods to derive this return. Also, the size of the direct payment flow has increased with the implementation of the MacSharry and Agenda 2000 reforms. The method currently used to update the 1993 database to 2001 does not take sufficient account of this policy change, with the result that the magnitude of the output effects observed in the simulations may be under-estimated. Further work to determine the sensitivity of the results to alternative formulations of these flows is desirable, as well as to determine the significance of other parameter values assumed in this calibrated model.

Our results show that intermediate decoupling of agricultural payments (the MTR proposal) would slightly under-achieve the NCCS target of 10% GHG reductions in agriculture, whereas full decoupling of agricultural payments would slightly over-achieve this target. The simulations do not incorporate the technology effect in emission reduction. This suggests that it would be possible to set a more ambitious target for emission reductions from the agricultural sector. In a further stage of development, the IMAGE model can be used to assess the efficiency of the overall target for agricultural sector emissions reductions in comparison to seeking these reductions in the non-agricultural sectors of the economy.

The FAPRI-Ireland model forecasts a reduction in agricultural emissions of 13.2%. A main difference in the FAPRI-Ireland results is the forecast 12% decline in sheep

numbers, whereas our simulations have found that sheep numbers will increase due to the significant fall in the cost of land to this enterprise.

Other impact analyses (Teagasc 2003, Commission 2003) suggest that decoupling will lead to an increase in farm incomes because the reduction in EU supplies will cause some upward pressure on market prices for agricultural products in the EU (though this will be limited by the size of import tariffs protecting the EU market) and because farmers will no longer be required to produce at a loss in order to qualify for eligibility for payments. Thus decoupling could be a win-win proposal, increasing overall income as well as reducing greenhouse gases. Future analysis of this issue will also be conducted using the IMAGE model.

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Appendix 1: Tables and figures

Figure 1: Nest Structure of Production Side of Model

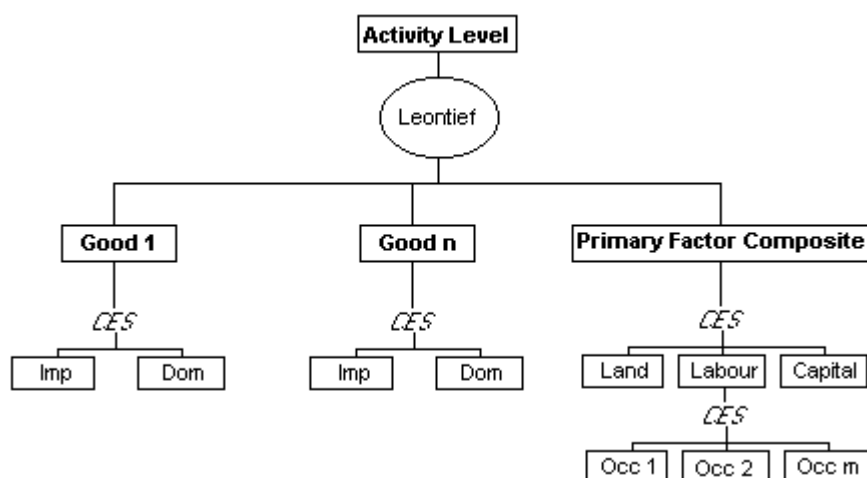


Table 1: GHG Reduction Targets for the Agricultural Sector

	Mt CO ₂ equivalent
Agricultural emissions, 1990	18.61
Minus reductions from:	
National herd (stocking)	0.50
National herd (feeding regimes)	0.70
Fertiliser use	0.90
On-Farm Forestry Sequestration	0.25
Manure Management	0.06
Total	2.41
Equals Emissions target, 2008	16.82

Source: National Climate Change Strategy (DoE, 2000)

Table 2: Land use and subsidies

	High Quality Agricultural land		Low Quality Agricultural land		Non-agricultural land	
	Usage (€m) ¹	Subsidy Removed (%)	Usage (€m)	Subsidy Removed (%)	Usage (€m)	Subsidy Removed (%)
Milk	362.1	0.0	100.7	0.0	0.0	-
Beef	263.2	82.9	73.2	82.9	0.0	-
Sheep	197.4	38.7	54.5	38.1	0.0	-
Other Livestock	22.5	0.0	6.2	0.0	0.0	-
Cereals	116.3	80.1	0.0	-	0.0	-
Fruit and Veg	24.5	0.0	0.0	-	0.0	-
Root and Green	7.0	0.0	0.0	-	0.0	-
Other Crops	1.9	0.0	0.0	-	0.0	-
Forestry	0.0	-	15.0	0.0	27.0	0.0

¹ Return to landowner

Table 3: Sources of agricultural GHG emissions in CO₂ equivalent

Industry	Share of Emissions	Emissions per euro output (kg)
Milk	24.7%	3.89
Beef	58.6%	6.47
Sheep and Wool	10.0%	10.47
Other Livestock	2.8%	1.04
Cereals	1.9%	3.11
Fruit and Vegetables	0.6%	0.59
Root and Green Crops	0.8%	1.42
Other Crops	0.6%	3.32

Source: Behan (2003) and own calculations.

Table 4: Results from Intermediate Decoupling (percentage change)

	Cost of Land	Land Usage	Total Costs to industry	Total Output of commodity	Sector's contribution to Ag. GHG emissions	Absolute change in GHG emissions (kt CO ₂ E)
Milk	-54.73	16.54	-7.03	0.29	0.08	13.07
Beef	164.55	-34.22	13.12	-16.66	-11.13	-1782.28
Sheep	-26.27	20.20	-12.81	19.07	2.19	349.87
Other Livestock	-54.73	21.33	-3.41	4.80	0.15	24.18
Cereals	125.36	-22.34	27.05	-17.65	-0.39	-62.20
Fruit and Veg	-55.15	22.59	-4.03	3.73	0.03	4.21
Root and Green	-55.15	21.19	-4.18	2.50	0.02	3.68
Other Crops	-55.15	20.33	-3.54	1.20	0.01	1.35
Forestry	-0.23	0.00	-0.31	0.03	0.00	-0.68

Table 5: Results from Full Decoupling (percentage change)

	Cost of Land	Land Usage	Total Costs to industry	Total Output of commodity	Sector's contribution to Ag. GHG emissions	Absolute change in GHG emissions (kt CO ₂ E)
Milk	-53.79	16.07	-6.88	0.28	0.08	12.62
Beef	169.98	-34.92	13.56	-17.10	-11.43	-1829.35
Sheep	-24.75	18.72	-12.05	17.68	2.03	324.37
Other Livestock	-53.80	20.71	-3.29	4.64	0.15	23.37
Cereals	126.34	-22.53	27.29	-17.84	-0.39	-62.87
Fruit and Veg	-54.95	22.45	-4.00	3.70	0.03	4.18
Root and Green	-54.95	21.06	-4.11	2.45	0.02	3.60
Other Crops	-54.95	20.09	-3.49	1.08	0.01	1.22
Forestry	-33.24	16.77	-11.51	11.28	-1.59	-254.82

Table 6: Results from Partial Decoupling, where land may lie fallow (percentage change)

	Cost of Land	Land Usage	Total Costs to industry	Total Output of commodity	Sector's contribution to Ag. GHG emissions	Absolute change in GHG emissions (kt CO ₂ E)
Milk	-20.00	4.26	-2.42	0.17	0.05	7.66
Beef	366.05	-53.86	27.92	-30.03	-20.07	-3212.60
Sheep	30.29	-15.84	14.52	-15.22	-1.74	-279.23
Other Livestock	-20.00	3.63	-0.27	-0.10	0.00	-0.50
Cereals	301.81	-40.34	62.88	-34.94	-0.77	-123.13
Fruit and Veg	-20.00	5.97	-1.60	1.33	0.01	1.50
Root and Green	-20.00	5.29	-1.95	0.81	0.01	1.19
Other Crops	-20.00	1.36	-1.55	-3.20	-0.02	-3.61
Forestry	-7.66	3.14	-3.14	2.36	-0.33	-53.31

Appendix 2: IMAGE Industries

I01Milk
I02Cattle
I03SheepWool
I04OLivestk
I05Cereals
I06FruitVeg
I07RootGreen
I08OtherCrop
I09Forestry
I10Fishing
I11AnimFeed
I12PcBeef
I13PcMutton
I14PcPorkPou
I15MilkProds
I16OtherFood
I17BevTob
I18PetCoal
I19ElecGas
I20Minerals
I21Chemicals
I22Machines
I23Textiles
I24WoodPaper
I25RubbrPlas
I26Construct
I27Dwellings
I28LodgCater
I29Communctn
I30CredInsur
I31OtherSers
I32Govrnment
I33TradeMarg
I34Transport