

LINCOLN TRADE AND ENVIRONMENT MODEL-ENVIRONMENTAL MODULES:

GREENHOUSE GAS EMISSIONS

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1. Brief overview

Direct emissions of carbon dioxide (CO₂) from the agricultural sector are low but emissions of methane and nitrous oxide by agriculture are much more significant in terms of the potential for global warming (MAF, 2001) compared to the effects of CO₂. For instance, using CO₂ as a base (i.e. 1), methane has a global warming potential of 21, and nitrous oxide 310 (MfE, 1999). Methane from livestock is produced from two possible sources: that is produced during the digestion process (“enteric fermentation”) and that is from the decomposition of ruminant fecal waste (“manure management”) (Lasseby et al., 1992). The amount of methane produced depends on the amount of feed intake as well as the type and quality of the feed. Nitrous oxide (N₂O), although emitted in much smaller quantities than either CH₄ or CO₂ is important because of its relative impact in terms of global warming potential. There are a number of sources of this gas arising from agricultural production. The first source is defined as animal waste management systems (AWMS). Six alternative regimes for treating animal manure, (anaerobic lagoon, liquid systems, daily spread, solid storage and drylot, pasture range and paddock, used fuel, other system) are identified in the Intergovernmental Panel on Climate Change (IPCC) guidelines. Emissions from agricultural soils make up a further source of N₂O, which are further divided into three sections - (1) direct emission of N₂O from agricultural soils (2) direct soil emissions of N₂O from animal production, and (3) indirect emissions of N₂O from nitrogen used in agriculture (IPCC Guidelines, 1996). Direct emissions from agricultural soils result from synthetic fertiliser application, the use of animal waste as fertiliser, nitrogen-fixing crops, and crop residues. Direct soil emissions of N₂O from animal production refers to the manure deposited by grazing livestock on pasture range and paddock and left there to decompose. Indirect emissions result from the atmospheric decomposition of ammonia and nitrogen oxides, and leaching.

Therefore, nitrogen and feed concentrate use are considered as the main factors behind the GHG production and various combinations of these two factors in different meat and dairy production systems are effective in determining the level of GHG emissions.

2. Environmental focus and approach used to link environment and trade

Table 1: Environmental focus and linking environment and trade

<i>Environmental Focus:</i>	-nitrous oxide emissions -methane emissions -greenhouse gas emissions
<i>Approach Used to Quantify Environment & Trade Link:</i>	-endogenized nitrogen usage through separate fertilizer market linked to agricultural goods -endogenized livestock numbers -endogenized greenhouse gas emissions based on number of animals and nitrogen usage

3. Changes in basic behavioral specifics

Domestic supply

In equation 1 the domestic supply function for beef and veal (qs_b) is presented. Here, subscript b stands for beef and veal, j stands for substitute commodities such as sheepmeat, pigmeat, raw milk and/or wool and subscript k shows feed products such as wheat, coarse grain and oil meals. The variables pp and pc represent the producer and consumer price level respectively. Therefore, domestic supply of beef and veal was specified as a function of own producer price, producer prices of substitute and complementary products and consumer prices of feed inputs at levels of the variables. The own-price elasticity of supply is shown by the superscript θ_{bb} and it is positive. The cross-price supply elasticity with respect to sheepmeat and other substitutes θ_{bj} and feed products θ_{bk} are negative as beef and sheepmeat are assumed to be gross substitutes and as feed products are inputs used for production.

The major dairy producing trading blocs were each sub-divided into regions to better reflect internal heterogeneity with respect to dairy production systems and environmental conditions, and to simulate their impact on the nitrous oxide and methane emissions. The domestic supply of the dairy sector was previously presented through the equations 2-4.

$$qs_b = \theta_{b0} pp_b^{\theta_{bb}} \prod_j pp_j^{\theta_{bj}} pc_k^{\theta_{bk}} ; \quad \theta_{bb} > 0, \theta_{bj} < 0, \theta_{bk} < 0 \quad 1$$

$$qsa_i = \alpha_{i0} pp_i^{\alpha_{ii}} \prod_j pp_j^{\alpha_{ij}} pc_k^{\alpha_{ik}} ; \quad \alpha_{ii} > 0, \alpha_{ij} < 0, \alpha_{ik} < 0 \quad 2$$

$$qs_i = qsa_i + qsb_i + qsc_i \quad 3$$

$$qs_l = \beta_{l0} qs_i^{\beta_{li}} pp_l^{\beta_{ll}} \prod_h pp_h^{\beta_{lh}} ; \quad \beta_{li} > 0, \beta_{ll} > 0, \beta_{lh} < 0 \quad 4$$

Animal numbers are of critical importance in determining the CH₄ and N₂O emissions for each country as well as for the supply of meat and dairy industries as the livestock are the major input into their own production. In the LTEM animal numbers in the meat and dairy industries were endogenized by using Jarvis's (1974) livestock supply response model. In Jarvis, livestock are considered as both consumption (milk, meat and hides) and capital (productive assets) goods. The fixed supply of animals at any moment creates a trade-off between the amount supplied to consumers and the retention of cattle in the form of investment. Producers are expected to retain livestock as long as their capital value (in production) exceeds their slaughter value. The cost of raising animals depends on how much the producer decides to feed the animal and on the time he or she fattens them before slaughter. Therefore a representative producer's problem becomes a

Figure 1a: A Temporary Rise in Beef Price in Period 3-4

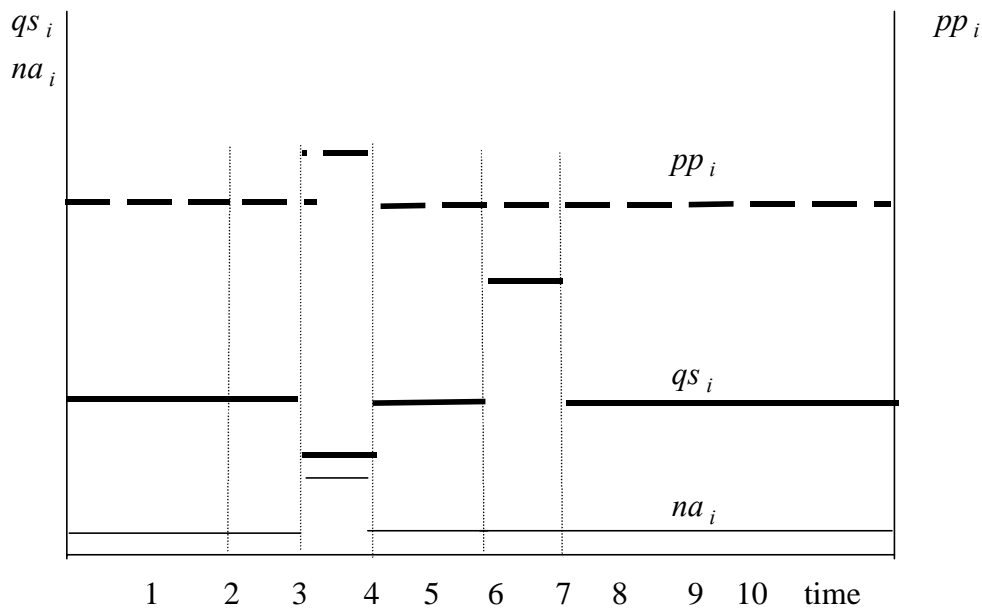
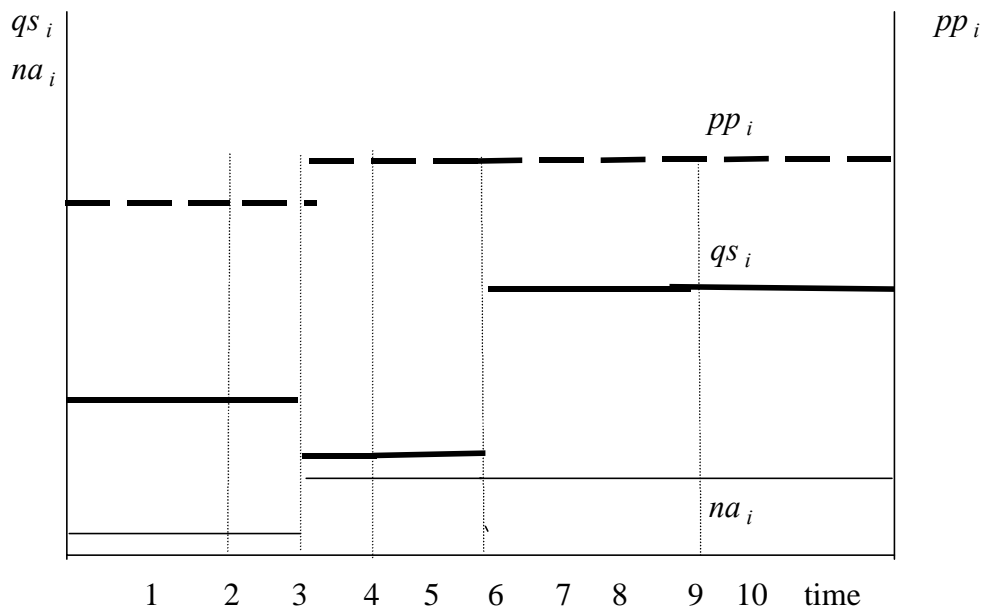


Figure 1b: A Persistent Rise in Beef Price from 3rd Period Onwards



Following Jarvis (1974), the number of animals used for meat and regional dairy production (Na_{ai}) in the LTEM was endogenized by specifying it as a function of various product prices such as; raw milk, beef and veal, sheepmeat, pigmeat and consumer prices of inputs such as; feed concentrates and nitrogen fertilizer, equation 7. In addition, the supply functions for beef and raw milk are extended to incorporate the number of animals and price of nitrogen fertilizer as explanatory variables, equations 8 and 9. In these equations the elasticity of raw milk and beef supply with respect to price of nitrogen fertilizer (α_2 and ω_2) is expected to be negative, and with respect to the number of cattle it is expected to be (α_3 and ω_3) positive⁴. Own-price elasticities are expected to be positive in equation 7 and negative in 8 and 9 respectively.

⁴ On the average a three year gestation lag is assumed for beef cattle to become productive before slaughtering and a two year lag is assumed for dairy cattle.

$$Na_{ai} = \chi_0 pp_i^{\chi_1} pc_n^{\chi_2} \prod_j \prod_k pp_j^{\chi_j} pc_k^{\chi_k} ; \quad \chi_1 > 0, \chi_2 < 0, \chi_j < 0, \chi_k < 0 \quad 7$$

$$qs_b = \theta_{b0} pp_b^{\theta_{bb}} pc_n^{\theta_{b2}} Na_{b(t-l)}^{\theta_{b3}} \prod_j \prod_k pp_j^{\theta_{bj}} pc_k^{\theta_{bk}} ; \quad \theta_{1bb} < 0, \theta_{b2} < 0, \theta_{bj} < 0, \theta_{bk} < 0 \quad 8$$

$$\theta_{b3} < 0 \text{ if } l < 3, \theta_{b3} > 0 \text{ if } l = 3$$

$$qs_{ai} = \alpha_{i0} pp_i^{\alpha_{i1}} pc_n^{\alpha_{i2}} Na_{ai(t-l)}^{\alpha_{i3}} \prod_j \prod_k pp_j^{\alpha_{ij}} pc_k^{\alpha_{ik}} ; \quad \alpha_{i1} < 0, \alpha_{i2} < 0, \alpha_{ij} < 0, \alpha_{ik} < 0 \quad 9$$

$$\alpha_{i3} < 0 \text{ if } l < 2, \alpha_{i3} > 0 \text{ if } l = 2$$

Domestic demand

The amount of applied nitrogen fertilizer and used feed concentrate in the production process is not only important because of the impact on supply but also because of the effect on GHG emissions. The demand for feed products (qd_k) in the LTEM is already modelled as intermediate demand by specifying it as a function of consumer prices of the own (pc_k) and substitute feed products (pc_j) and supply amount of raw milk (qs_i) (meat (qs_b)) and substitute products (qs_j) (qs_h)), equation 10.

In order to endogenize the amount of nitrogen fertilizer used for production of dairy in different regions, conditional input demand function for nitrogen fertilizer is estimated for each region, equation 11. In this equation, the demand for nitrogen use per hectare for example in region a (Na) is specified as a function of relative prices of the feed concentrates (pc_k) to the nitrogen⁵ (pc_N) and quantity supplied of raw milk per hectare in region a (qs_{ai}) (or beef (qs_b) for meat sector).

$$qd_k = \iota_{k0} pc_k^{\iota_{k1}} qs_{it}^{\iota_{k2}} \prod_j \prod_f qs_{jt}^{\iota_{kj}} pc_{ft}^{\iota_{kf}} ; \quad \iota_{k1} < 0, \iota_{k2} > 0, \iota_{kj} > 0, \iota_{kf} > 0 \quad 10$$

$$Na = \beta_0 (qs_{ai})^{\beta_{i1}} \left(\frac{pc_k}{pc_N} \right)^{\beta_{i2}} ; \quad \beta_{i1} > 0, \beta_{i2} > 0 \quad 11$$

4. Environmental sub-module

To simulate the impact of changing market conditions on production and thus the environment, the factors affecting greenhouse gas emissions have been specified separately and for the purpose of this study, emissions from milk cattle are taken into account. The principal determinants of gas from this source are livestock numbers, feed intake per head, and methane production per unit intake by feed type (Lassey *et al.*, 1992). Most animal waste decomposes aerobically on pasture in New Zealand, resulting in relatively low levels of methane emissions from manure management for this country (MfE, 2000). Lassey *et al.* (1992) also assesses emissions from animal wastes, and from effluent processing plants such as abattoirs and dairy factories to be of relatively minor importance.

The challenge of incorporating methane and nitrous oxide into the LTEM model is to produce an equation (an environmental sub-module) which links all agricultural sources of these greenhouse gases to domestic production, and measures the methane and nitrous oxide emissions in physical terms. Therefore emission factors are crucial in this process as well as the effect of different production systems, domestic and border policies. The IPCC in its guidelines produces

⁵ Nitrogen price data was obtained from the FAO database (FAOSTAT, 2002) using urea as the closest available fertiliser.

default emission factors for different sources of gases, for a maximum of eight regions of the world⁶. Greenhouse gases (GHG) are incorporated into the model through the equation 12. In this equation GHG emissions from raw milk production in region a is specified as a function of applied nitrogen fertilizer (n_a) and number of animals (Na_a) in region a which are endogenous to the model. The CH_4 and N_2O emission factors are implicit in the coefficients (ξ , ζ) and values of these coefficients are provided by Clough and Sherlock (2001) (see Appendix Tables A1 and A2 for calculation of coefficients for greenhouse gas production), equation 12. The CH_4 and N_2O emissions from these sources are converted to their CO_2 equivalents by multiplying with their respective weights (21 and 310) to give CO_2 equivalents⁷. The total emission level is equal to the sum of emissions in each region, equation 13.

$$GHG_{amt} = \xi Na_{amt} + \zeta(n_{at}, Na_{at}) \quad 12$$

$$GHG_{mt} = GHG_{amt} + GHG_{bmt} + GHG_{cmt} \quad 13$$

The calculation of coefficients for methane and nitrous oxide production from livestock systems is based on the IPCC methodology for greenhouse gas inventories⁸. Methane and nitrous oxide are separated into their sources. Default emission factors provided by the IPCC are used for the calculation of coefficients in most countries. In the case of nitrous oxide production in New Zealand, the emission factors are based on recent research, and differ from the default IPCC values. For the purposes of the model used in this study, coefficients representing the total methane and nitrous oxide produced from all livestock sources, for each animal type were calculated. Soil scientists combined the emission factors for the various sources into one coefficient for the production of nitrous oxide and one for the production of methane per animal. A single coefficient for the nitrous oxide emitted from Nitrogen fertilizer was also calculated, constant across animals and countries.

⁶ Naturally therefore, these values will vary considerably within each region, and New Zealand, as have many other countries, has carried out in-depth research to provide more accurate emission factors.

⁷ The same equation is used to measure nation level emissions from beef and sheep also.

⁸ For details on these guidelines, see www.ipcc.org for Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Workbook.

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Appendix

Table A1: The calculated coefficients for nitrous oxide for different animal classes*-(tonnes of N₂O per animal per year)

<i>Country</i>	<i>Animal Class</i>	<i>Amount</i>
New Zealand	Sheep	0.000396
	Beef	0.00244
	Dairy	0.003556
Other countries (based on default values provided by the IPCC)	Sheep	0.00809
	Beef	0.00243
	Dairy	0.003117

*: The coefficient for N₂O emitted from Nitrogen fertilizer is 0.0251 tonnes of N₂O per tonne of fertilizer-N.

Table A2: The calculated coefficients for methane for different animal classes-(tonnes of CH₄ per animal per year)

<i>Animal Class</i>	<i>Amount</i>
Sheep	0.01528
Beef	0.00244
Dairy	0.07769