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Technical Annex

# The WTO, Agricultural Trade Reform and the Environment: Nitrogen and Agro-chemical Indicators for the OECD

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This document is the technical annex to the full paper "The WTO, Agricultural Trade Reform and the Environment: Nitrogen and Agrochemical Indicators for the OECD" which is available separately.

## *Modifications to the Standard GTAP Trade Model*

Our first modification, which allows additional input-substitution, is guided by the approach of OECD (2005, chapter 6). Agro-chemicals are permitted to substitute for land in crop production, and purchased feedstuffs can substitute for land in livestock production. We also allow for substitution among individual feedstuffs in livestock production (in place of the standard Leontief formulation). CES elasticities (taken from OECD 2005) are 0.1 between chemicals and land for the crop sectors, and 0.4 between composite feeds and land for the livestock production sectors. We use a value of 0.9 for the CES feedstuffs substitution elasticity, being a share-weighted average derived from the elasticities of substitution estimated by Surry (1990). Substitution between capital and skilled and unskilled labour is modelled with CES elasticities identical to those used in the value-added nest in the standard GTAP formulation. Finally, some substitution is allowed between the capital-labour composite and the land-chemicals-feed composite, with a CES elasticity of 0.1 (OECD, 2005).

The second GTAP modification is to incorporate agricultural production quotas. Required data are market prices (PS) and marginal production costs (PQ). In quota cases where the ratio PQ/PS <1, the quota is assumed to be binding. For the EU milk quotas, data are from Jensen and Frandsen (2003) for each EU15 country, and production-weighted averages of them are used here for the EU sub-regions and indicated binding quotas in all cases. Lips and Rieder (2005) provide data for Switzerland that we assume applies to the entire EFTA region. Milk quotas are binding in Canada according to Meilke, Sarker and Le Roy (1998) and Karl Meilke (personal communication, 2003). Modelling the EU's sugar quotas is more complicated, owing to the existence of three quotas (A, B and C). We chose to adopt an approximate representation as a single quota. Average price and marginal cost data for each EU15 country were taken from Frandsen et al. (2003) and aggregated up to our EU regions using sugar production data as weights.

### *The Nitrogen Model*

The ways in which nitrogen losses from farming activities affect the natural environment and impact on people and economies are complex and not fully understood. However, environmental indicators can be used to draw attention to possible pressure points between agricultural activity and the environment. Nutrient balances measure the surplus of nutrients not taken up by plants and assumed to finish up in air, water or soil. Thus they are indicators of environmental impacts, since the precise relationship between such surpluses and actual environmental impacts remains unclear (Vanongeval and Bomans, 1997).

In the soil, organic nitrogen compounds are transformed in the presence of micro-organisms into nitrates or nitrites (De Clercq et al., 2001; Vanongeval and Bomans, 1997). Denitrification is the process that converts nitrates and/or nitrites to gaseous nitrogen components. Ammonium in the soil solution (e.g., from urea fertiliser or animal manures) that is close to the surface can volatilise as ammonia and affect air quality. Volatilisation can also occur from stored manures and animal housing. Leaching of nitrogen occurs when nitrate is transported beyond the root zone by drainage water.

The linkage between the balance measure and actual nitrogen losses is explored by Ledgard, Crush and Penno (1998) and Ledgard, Penno and Sprosen (1999) in the case of New Zealand dairy farms. Nitrogen surpluses were measured using the farm-gate method, as indicators of potential nutrient losses to the environment. Actual losses of nitrogen due to the various processes described above were then measured over a three-year period. In all cases studied, the sum of the nitrogen outputs and the measured nitrogen losses were similar to the sum of the nitrogen inputs. This work also indicated the relative importance of denitrification, volatilisation and leaching and concluded that the main potential for environmental impact on such farm systems was from nitrate leaching to groundwater, which accounted for approximately 40 percent of the total nitrogen surplus. A marked increase in leaching also occurred with increasing use of nitrogen (urea) fertiliser on pastures.

Vanongeval and Bomans (1997) provide examples of correlations between nitrogen balance (soil-surface) indicators and nitrogen losses for farm regions in Belgium. They concluded that for catchment areas with a nitrogen surplus above 100 kg N/ha, a clear and positive relationship existed between nitrogen surplus and nitrogen loss. For sites where the surplus was below 100 kg N/ha, the link between surplus and loss appeared weaker, perhaps indicating that at such levels of surplus, the role of factors such as soil type, soil use and slope are as important as the surplus.

Bechmann, Eggestad and Vagstad (1998) examine the correlation between nitrogen surface balances and nitrogen leaching in four agricultural catchments in Norway. Across these catchments and the years 1992-96, nitrogen balances varied between 30 and 85 kg N/ha, well below the 100kg/ha threshold suggested by Vanongeval and Bomans. Perhaps not surprisingly, they found a low correlation between surface balances and leaching when all catchment and annual data were pooled. A much higher correlation was found between nitrogen leaching in autumn and the surface balance, when only catchments with similar soil properties and years with similar weather conditions were included. This appears to support the Vanongeval and Bomans conclusion regarding the importance of other factors such as soil type when surface balances are relatively low.

We write the OECD model components as follows: equation (1) gives the balance as the difference between nitrogen input and output; equation (2) identifies nitrogen output as the sum of crop and fodder outputs and pasture grass consumption; and equation (3) indicates the various components that together comprise total nitrogen inputs.

Soil-surface nitrogen balance (SSNB), country i:

(1) $SSNB_i = NI_i - NO_i$

Nitrogen output (NO):

(2) $NO_i = \Sigma n_{ki}Q_{ki} + \Sigma n_{ki}HF_{ki}$

Nitrogen input (NI):

(3) $NI_i = F_i + LM_i + MW_i + BNF_i + AD_i + SPM_i$

(3.1) $F_i = \Sigma fn_{ki}CF_{ki} + \Sigma fn_{ki}OF_{ki}$

(3.2) $LM_i = \Sigma lm_{ji}L_{ji}$

(3.3) $BNF_i = \Sigma nf_{ki}A_{ki} + nfx_iLD_i$

(3.4) $AD_i = ldn_iLD_i$

(3.5) $SPM_i = \Sigma ns_{ki}QS_{ki}$

where: $n_{ki}$ = nitrogen uptake to produce a tonne of the kth harvested crop or forage crop; $Q_{ki}$ = quantity of the kth harvested crop; $HF_{ki}$ = quantity of the kth harvested forage crop or total pasture consumption; $F_i$ = total quantity of N from fertiliser; $fn_{ki}$ = quantity of N per unit of kth fertiliser; $CF_{ki}$ = quantity of kth chemical fertiliser; $OF_{ki}$ = quantity of kth organic fertiliser; $LM_i$ = livestock manure N production; $lm_{ji}$ = N manure per head per annum of jth livestock type; $L_{ji}$ = total inventory of jth type of livestock; $MW_i$ = total manure withdrawals from agriculture; $BNF_i$ = biological N fixation; $nf_{ki}$ = N fixation per hectare of kth legume crop or pasture; $A_{ki}$ = planted area of kth legume crop or pasture; $nfx_i$ = N fixation per hectare by free-living soil organisms; $LD_i$ = total area of agricultural land; $AD_i$ = atmospheric deposition of N; $ldn_i$ = atmospheric deposition of N per hectare; $SPM_i$ = N contained in seeds and planting materials; $ns_{ki}$ = N content of seeds and planting materials for kth crop and $QS_{ki}$ = total quantity of seeds and planting materials for kth crop.