Tradable Emission Permits in Agriculture

– A Regional Approach -

Ignacio Pérez

Institute for Agricultural Policy, Bonn University

Structure of the Seminar

1. Introduction
2. Economic Theory of tradable permits
3. Modelling approach
4. The CAPRI Model
5. A GHG Emission Accounting Module
6. Some results
7. Conclusions

Global Warming and Agriculture

- Agriculture and climate are mutually dependant:
  - Important source and sink of GHGs (methane and nitrous oxide)
  - Important receptor of climate change effects (water stress, lower yields, …)
- Agriculture may benefit from the current negotiations on climate change through emission selling (dependant on sectoral abatement costs)
- Different modelling tools have been applied to estimate these 'variables' in combination with different policy set-ups (ASMGHG, AROPAj, CAPRI, …)
- This requires the combination of bio-physics and economics (not an easy task)

Climate Change Regulation

Date of Agreement	Date of entry force	Place of Agreement	Title of Agreement	Parties
22.03.1985	22.09.1988	Vienna	Vienna Convention for the Protection of the Ozone Layer	188
16.09.1987	01.01.1989	Montreal	Montreal Protocol on Substances that deplete the Ozone Layer	187
09.05.1992	01.08.1994	New York	United Nations Framework Convention on Climate Change (UNFCCC)	189
11.12.1997	18.02.2005	Kyoto	Kyoto Protocol to the United Nations Framework Convention on Climate Change	36 Annex I 93 Non-Annex I

- The IPCC compiles technical and economic information relevant to understand the scientific linkages of climate change and publishes periodically validated procedures for the calculation of emission factors
- The Kyoto Protocol to the UNFCCC is currently the most ambitious international effort in global warming emission control (Annex I countries: -5% 1990-2012, -8% for the EU)

Kyoto Instruments of Abatement

The Kyoto Protocol introduced several innovative mechanisms to help Annex I countries meet their targets at a lower cost:

- **Joint Implementation (JI):** Annex I countries are allowed to transfer to or acquire from any other such party Emission Reduction Units (ERUs), resulting from emission mitigation projects
- **Clean Development Mechanism (CDM):** bilateral agreements between Annex I and non-Annex I countries, Certified Emission Reductions (CERs) attached to GHG mitigation projects
- **International Emission Trading (IET):** industrial countries receive emission permits equivalent to their emission reduction objectives in the commitment period and are allowed to trade them

The European Trading Scheme

- Council Directive 2003/87/EC (10/2003), operational in 01/2005:
  - It applies to a list of energy and industrial production activities and covers all GHGs included in Annex A of the Kyoto Protocol
  - It defines a coordinated ETS over all Member States
  - It foresees an implicit voluntary opt-in for other sectors through possible amendments
  - It foresees coordination with existing trading schemes
- Trade of allowances has been already implemented in Europe for other environmental problems:
  - Quotas for ozone depleting substances (Montreal Protocol)
  - Fish catch quotas (Common Fisheries Policy)
  - Milk quotas (Common Agricultural Policy)

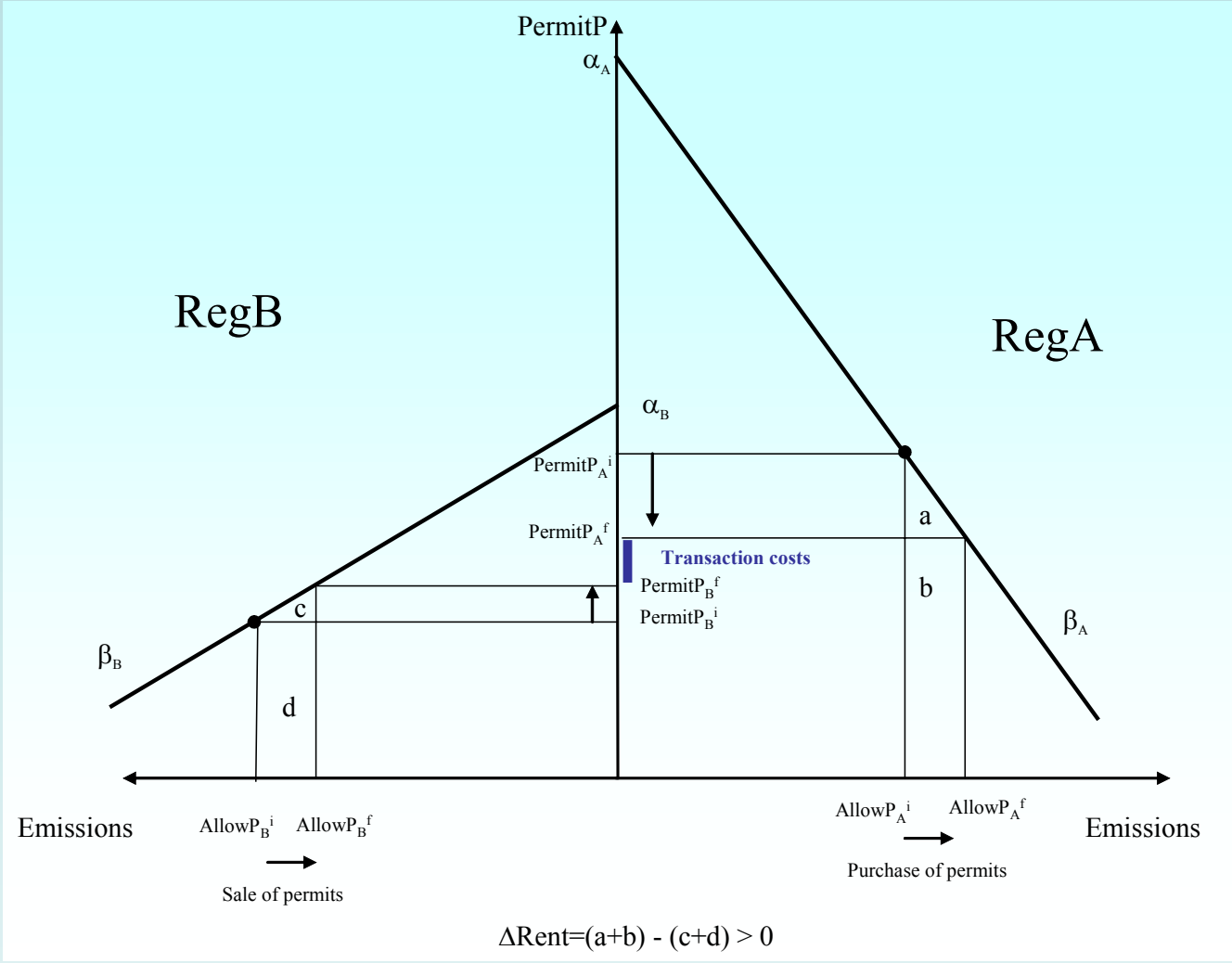
Some micro-economics…

The implementation of permit markets for abatement of agricultural GHG emissions is defended based on the following arguments:

- *Cost effectiveness*: market-based instruments perform better than command and control instruments →emission pricing allows firms to choose a production program based on their individual costs of abatement (equi-marginality principle)
- *Technological change (dynamic efficiency):* explicit emission prices introduce an ongoing incentive for firms to continually reduce their emissions
- *Regulatory flexibility*: permit trading schemes are also often preferred to taxes because emission rights can be allocated once a political process has decided upon the total level of emissions permitted

… however the replacement of CAC regulation is **unrealistic !**

A graphical representation



Structure of the Modelling Approach

General characteristics:

- Grandfathering: distribution of permits among agricultural producers of permits free of charge and linked to historical emission records
- Inter-regional emission trading at European level allowed
- Explicit consideration of transaction costs (fix and variable)
- No enforcement penalties (no cheating)

… and more specific assumptions:

- 85% cap on regional 2001 GHG emissions (methane and nitrous oxide from agricultural sources) assumed as initial restriction
- Transaction costs:
  - ✓ 10 Mio € pre-implementation costs (2 Mio per year, 5y amortisation)
  - ✓ 5 €/ton variable costs for trading within a MS and 10 €/ton outside

Some Identities Used

- 'Emission targets' are considered 'permit allowances' (1 ton of CO_2^{eq} = 1 permit)
- 'Marginal abatement costs' approached through the shadow values of the regional emission targets (binding restrictions in regional supply optimisation models)
- 'Marginal abatement costs' equal 'permit prices' (MAC = PermitP)
- 'Marginal abatement cost curves' are approached through 'permit demand functions' (regional supply models behaving as consumers of emission permits)

Regional Emission Restrictions

An upper limit on regional emissions is directly included as an aditional restriction in the profit maximisation problem:

$$\max \quad \pi = f(x)$$
$$s.t.\ g(x) \le G \quad [\lambda] \quad \Leftrightarrow \quad \frac{\partial \pi}{\partial x} = 0 = \frac{\partial f}{\partial x} + \lambda \frac{\partial g}{\partial x} + \mu \frac{\partial e}{\partial x}$$
$$e(x) \le E \quad [\mu]$$

Where:

Π = profit

μ = shadow value of the emission abatement target

E = upper bound on emissions

λ = shadow value of the other restrictions

G = allowed level of all other constraints in the model

Permit Allowance (t CO2eq)

Permit Price (€/ton)

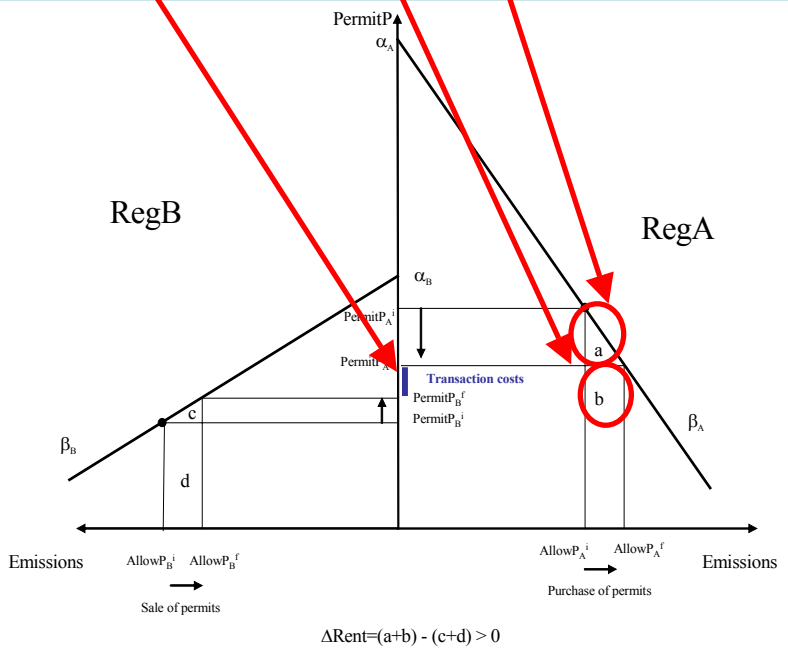
Tradable Permits: Objective Function

$$Max\ \ Obje = \sum_r \left[\frac{1}{2}\left(PermitP_r^{\,i} - PermitP_r^{\,f}\right) * \left(AllowP_r^{\,f} - AllowP_r^{\,i}\right) + \left(AllowP_r^{\,f} - AllowP_r^{\,i}\right) * PermitP_r^{\,f} - \left(BuysIn_r + BuysOut_r\right) * VarTC\_Inst - \left(BuysIn_r * VarTCIn + BuysOut_r * VarTCOut\right) \right]$$

Rent A: rectangle a

Rent B: rectangle b

Transaction costs: part of b



Tradable Permits: Constraints

$$AllowP_r^f = AllowP_r^i + (BuysIn_r + BuysOut_r) - (SalesIn_r + SalesOut_r)$$

$$\sum_r [SalesOut_r] = \sum_r [BuysOut_r] \qquad \sum_{r \in MS} [SalesIn_r] = \sum_{r \in MS} [BuysIn_r]$$

$$PermitP_r^i = \alpha_r + \beta_r * AllowP_r^i \qquad PermitP_r^f = \alpha_r + \beta_r * AllowP_r^f$$

Where:

BuysIn = permits bought by region r from national regions (same Member State)
BuysOut = permits bought by region r from foreign regions
SalesIn = permits sold by region r to national regions (same Member State)
SalesOut = permits sold by region r to foreign regions

Plus initialisation of parameters:

$$\beta_r = (\mu_r^{step-2} - \mu_r^{step-1}) / (emission_r^{step-2} / emission_r^{step-1})$$

$$\alpha_r = \mu_r^{step-1} - \beta_r * emission_r^{step-1}$$

$$VarTC\_Inst = TC\_Inst / \sum_r (BuysIn^{step-1} + BuysOut^{step-1})$$

Justification and Alternatives

- Approach based on 'quota trading' theory
- Several iterations for achievement of an optimal solution (problem: 200 regional trading agents / optimisation models)
- 'Area change' and not 'total area' below the permit demand function maximised for modelling purposes:
  - No need of spatial arbitrage conditions (to ensure price differentiation)
  - No need of 'real' marginal abatement cost curve
  - Possibility to model different transaction costs for different permit flows
  - And same results achieved (equi-marginality fulfilled)
- An alternative to direct modelling of emission targets is the explicit consideration of carbon prices/taxes in the objective function

What is CAPRI (I)?

- **CAPRI: C**ommon **A**gricultural **P**olicy **R**egionalised **I**mpact analysis
  - European research project
  - Financed by DG Research (FP4, FP5 and FP6)
- **Objective**: design und use of an EU-wide Model for the regionalised analysis of the Common Agricultural Policy (CAP)
- **Properties**: partial equilibrium model, comparative-static (price dynamics are being introduced), regionalised, endogenous prices, …
- **Contents:** economic model, data base, software tools (GAMS code)
- **Application**: Agenda 2000, Mid-Term Review, WTO Proposals, …

What is CAPRI (II)?

- A “multi-purpose” modelling system for European agriculture which allows the analysis of:
  - Market policies (administrative prices / import tariffs / TRQs / preferential trade agreements)
  - Premium systems / quotas /set-aside at regional level
  - Environmental policies
  - Changes in exogenous drivers (population / inflation / exchange rates / consumption behavior / technical progress)
- Regarding:
  - Supply / demand / trade flows
  - Land use (hectares) / herd size / yields / input use
  - Producer and consumer prices, income indicators
  - Environmental indicators (based on nutrient flows)
  - Welfare effects

The Supply Component

- Each regional unit has its own optimisation model
- Each model has the same structure (variables and equations), but differs in parameters from models in other regions
- They are aggregate non-linear programming models, i.e. they maximize an objective function (revenue + premiums – costs) under constraints (land balance, quotas, set-aside obligations, etc)
- A non-linear cost function is part of the objective function:
  - It is partially based on econometric estimation
  - It pretends to ‚dampen' over-specialization
  - It allows for calibration to the base year situation and for model behavior based on observed statistical data (PMP terms)

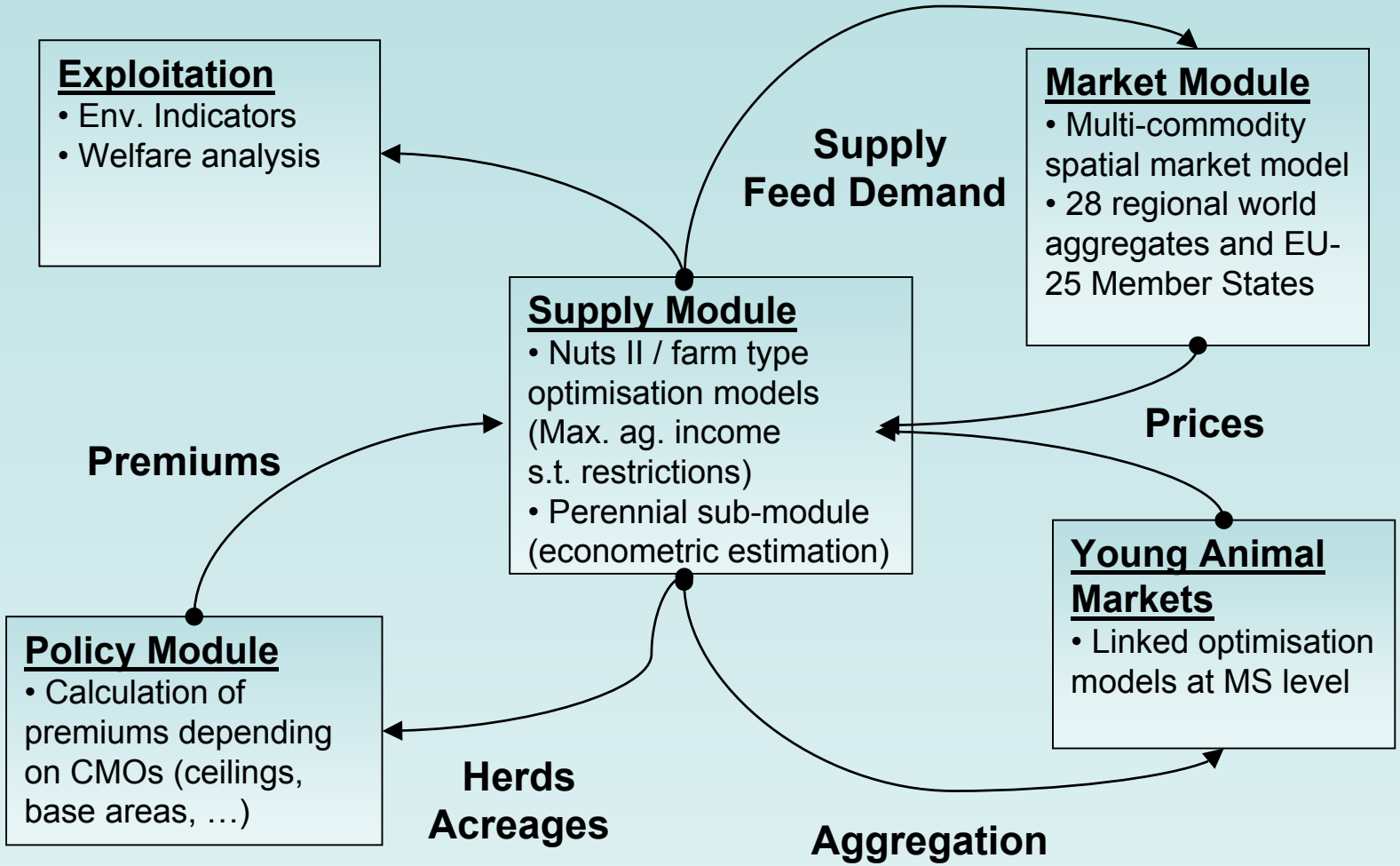
The Supply Component

- The **objective** accounts for:
  - Revenues from selling products
  - Costs from buying variable inputs (fertiliser, plant protection, feed etc.)
  - Costs for other production factors (capital, labor, information) ⇔ the non-linear part
  - A risk component for the A,B,C sugar-beet regime
- The **constraints** comprise:
  - Arable and grass land
  - Feed requirements (energy, protein, fibre, min/max of certain feeding stuff, etc) per animal type
  - NPK balances
  - Set-aside obligations
  - Milk quotas, emission quotas, …

The Market Component

- It is a spatial multi-commodity Model (Armington approach: imperfect substitution between imports and domestic sales)
- It comprises supply as well as feed, human consumption and processing demand:
  - for 42 products
  - and 28 countries/country aggregates (e.g. US, Canada, Australia & New Zealand, free trade developing countries, high tariff traders, India, China, ACP countries, …, rest of the world)
- Includes bilateral trade flows, import tariffs (including TRQs / import tarifs / preferential agreements)
- Plus market interventions and export subsidies by the EU

Overall Structure of CAPRI



GHG Emission Module

- Accounting of GHG Emissions based on IPCC Methodology (common guidelines)
- Estimation of emission factors for methane and nitrous oxide
- Several sources included: enteric fermentation, manure management, agricultural soils (from nitrification and denitrification effects)
- Total emissions as non-binding constraint (for simulation purposes)
- 'Half-passive indicators' based on certain variables: nutrient flows in agriculture, gross energy intake by animals, climate regions, …

What is behind? A Feeding Module

Animal activities demand nutrients which are supplied by crop feeding activities:

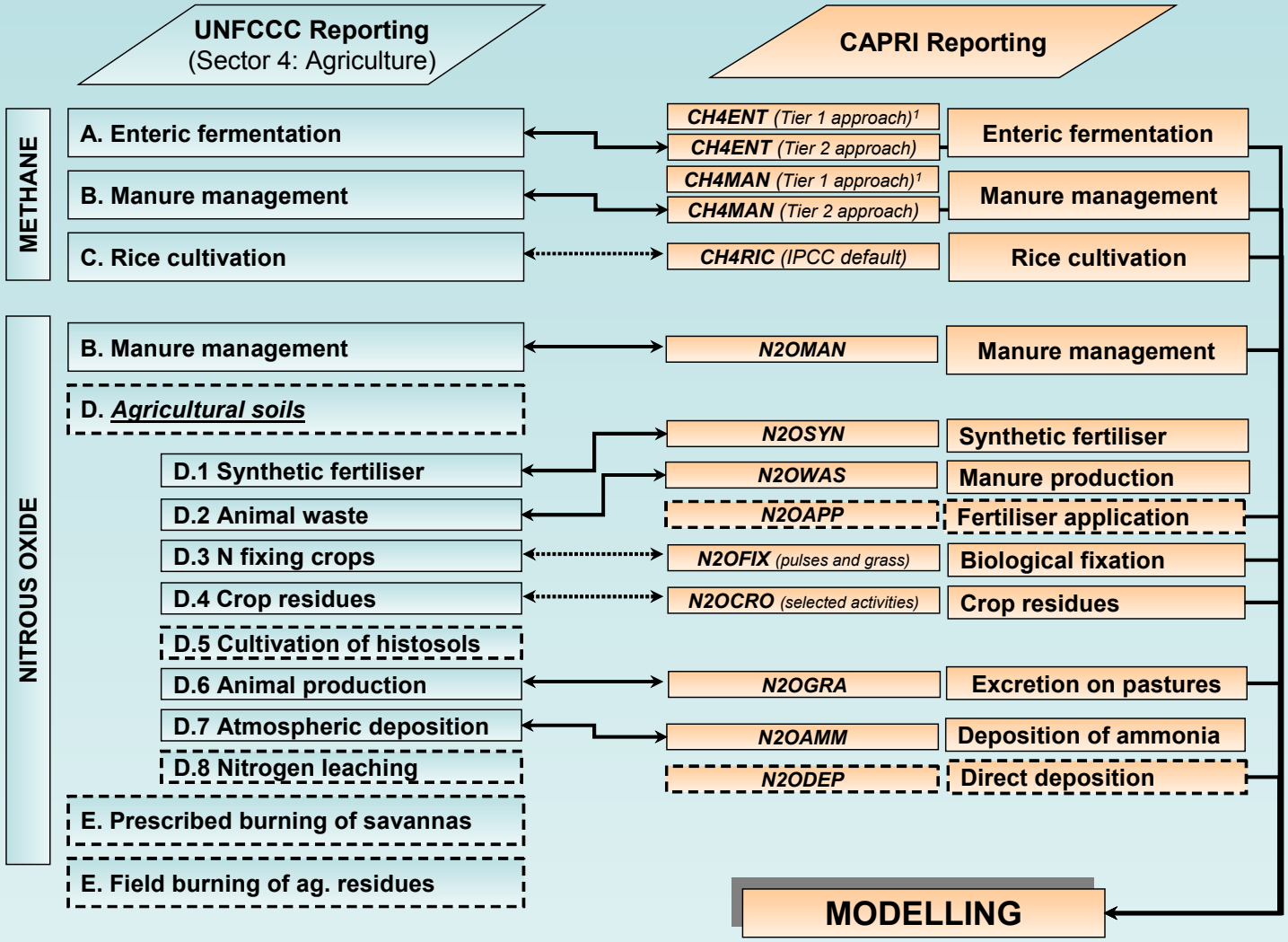
- Energy, protein, fiber and dry matter requirements are calculated for 16 animal activities based on bio-physical equations
- Need of nutrients by animals and availability of them on feeding aggregates defined: requirement functions for each animal category are estimated depending on the ingestion capacity, live weight, days of production and yields
- Fodder prices are estimated for non tradable feeding compounds in the model.

What is behind? A Fertilising Module

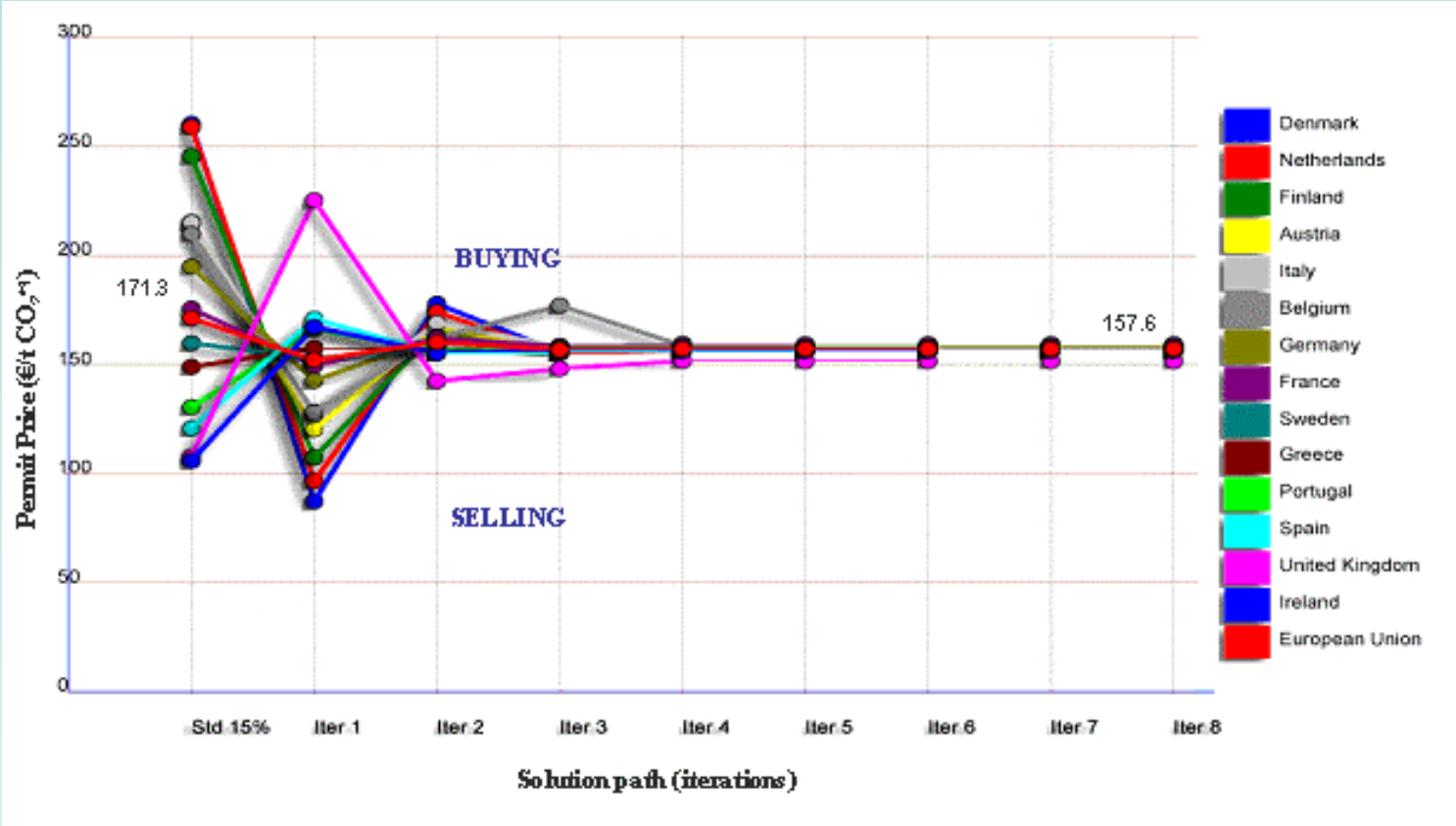
Crop activities demand nutrients which are partially supplied by animal activities:

- Crops are 'consumers' which need to cover their NPK nutrient needs through the application of fertiliser (anorganic and organic)
- Nutrient correction and nutrient availability factors are included and specified in order to calibrate observed data on national mineral fertiliser consumption and regional manure production
- All sources and sinks of nitrogen in agriculture are introduced into the model (atmospheric deposition, biological fixation, …) → exports and imports of nitrogen are considered

What is behind? Emission Inventories



Results: Internal Solution Path



Results: Permit Flows

	Initial Permit Price (Std 85%) Euro	Final Permit Price Euro	Total amount of permits 1000 Units	Purchases inland 1000 Units	Purchases abroad 1000 Units	Sales abroad 1000 Units	Total purchases 1000 Units	Total Sales 1000 Units
European Union	**171.3**	**157.6**	**271393**	**952**	**5984**	**5984**	**6936**	**6936**
Denmark	260.4	161.2	7448	0	469	0	469	0
Netherlands	259.0	161.2	13554	0	786	0	786	0
Finland	245.6	161.2	3546	0	198	0	198	0
Austria	215.3	161.2	5714	0	240	0	240	0
Italy	215.2	160.9	27573	37	1205	0	1242	37
Belgium	210.0	160.8	7119	4	276	0	279	4
Germany	195.0	160.8	48496	5	1704	0	1709	5
France	175.7	159.5	68821	690	1102	0	1792	690
Sweden	159.9	159.1	4714	12	5	0	17	12
Greece	149.0	154.2	5999	33	0	52	33	85
Portugal	130.5	151.9	5091	5	0	163	5	168
Spain	120.8	151.8	28358	90	0	1681	90	1771
United Kingdom	108.0	151.2	33141	76	0	2982	76	3058
Ireland	105.9	150.9	11819	0	0	1106	0	1106

Results: Income Effects

	85% emission standard [2001] differences to : GHG Inventories Base Year [2001]			85% emission standard + trade [2001] differences to : 85% emission standard [2001]		
	Agricultural income Mio Euro	Revenues/costs from emission trade Mio Euro	Total Income Mio Euro	Agricultural income Mio Euro	Revenues/costs from emission trade Mio Euro	Total Income Mio Euro
European Union	-5920.67		-5920.67	630.67	-66.6	564.06
Belgium	-108.34		-108.34	48.01	-44.4	3.61
Denmark	-261.73		-261.73	95.92	-75.7	20.27
Germany	-1412.37		-1412.37	412.46	-274.7	137.72
Austria	-174.13		-174.13	49.53	-38.6	10.89
Netherlands	-356.64		-356.64	148.43	-126.6	21.83
France	-992.78		-992.78	238.91	-181.2	57.71
Portugal	-9.21		-9.21	-20.70	24.5	3.79
Spain	-565.27		-565.27	-192.24	253.3	61.06
Greece	-215.54		-215.54	-4.26	7.7	3.44
Italy	-836.80		-836.80	254.85	-194.4	60.45
Ireland	-143.11		-143.11	-134.15	166.9	32.76
Finland	-111.00		-111.00	34.16	-31.9	2.22
Sweden	-175.07		-175.07	2.19	-0.9	1.25
United Kingdom	-558.67		-558.67	-302.42	449.5	147.08

Conclusions (I)

- The CAPRI Model allows for the combined representation of economic and environmental effects of European agricultural policies
- Environmental constraints can be easily modelled as physical restrictions in agricultural supply optimisation models
- Bio-physical functions and basic environmental / trade economics can be applied to the case of GHG emission permits
- The estimated indicators might be of relevance for the ongoing international negotiations on climate change mitigation

Conclusions (II)

- Assuming a 15% restriction on GHG agricultural emissions in year 2001:
  - Emission trading proves to be a cost effective solution for Member States due to the heterogeneity of their marginal abatement costs (∅ MAC from 171 to 158 €/t)
  - Income effects of this instrument (∅ 630 Mio €) and effective trade (∅ 6.9 Mio transactions) depend heavily on the transaction costs linked to its implementation.
- Some comments:
  - No sinks are considered in the analysis, no abatement technologies (only output and 'restricted' yield response)
  - The response of the model depends on specific restrictions and calibration approach (price elasticities →non-linear cost functions)

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Merci pour votre attention !!!