Non-CO_2 greenhouse gas emissions from agriculture : analysing the room for manoeuvre for mitigation, in case of carbon pricing[1]

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Abstract: Relationships between the greenhouse effect and agricultural activity are usually and firstly considered in terms of the impact of climate change on agriculture. But in reverse, farmers and herders may react to a climate policy imposing a carbon price to GHG-emitting activities, and possibly contribute to the emissions mitigation as well as to carbon sequestration. The degree of efficiency of the reactions will vary across regions of the world and across activities. A methodology considering risk associated with technology changes is proposed for estimating and accounting these reactions under production and resource constraints. For a business-as-usual scenario quantified by the integrated assessment model Image, decisions concerning land-use and alternative practices are modeled. Results indicate that main agricultural activities provide little room for manoeuvre for emissions mitigation.

JEL classification: N50, Q19, Q24, Q25, R14,

1. The climate change issue and agriculture

Is it reasonable to think of mitigating agricultural GreenHouse Gas (GHG) emissions through a climate policy based on carbon pricing? The answer is not straightforward, it is manifold, and with many respects, region-specific. First, it depends on the gravity of the greenhouse issue, still uncertain, even controversial at the current stage of knowledge. However, waiting for the proof of relevance of the issue might induce delays and reduce the room for manoeuvre to avoid major impacts of climate change. Second, it depends on the capacity for reaction of the sectors that represent main GHG sources, specially because of their fossil energy consumption. The potentials of emitting sectors for mitigation and the costs of abatement or sequestration options are currently debated.

In its climate change 2001 report on Mitigation, the Intergovernmental Panel on Climate Change (IPCC) clearly assesses that the transport and the energy production sectors constitute the main anthropogenic GHG sources, and states that "agriculture contributes only about 4% of global [i.e. world-wide] carbon emissions from energy use, but over 20% of anthropogenic GHG emissions in terms of MtC-eq/yr[2] mainly from methane [55-60% of total CH_4 emissions] and nitrous oxide [65-80% of total N_2O emissions] as well as carbon from land clearing".

Emissions from agriculture occur through different processes (IPCC, 1996a, Alcamo et al., 1998): enteric fermentation and animal waste disposal and fermentation, anaerobic process when growing rice, nitrification and de-nitrification linked with fertilisation, and also land clearing, the burning of biomass, of fuel wood, of agricultural waste, and of savannah. But agriculture can contribute to C sequestration efforts, mainly through reforestation, forest management, bio-fuels and soil carbon stocking[3]. The sector can also participate in the abatement process, mainly through changes in practices and land uses.

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[2] MtC-eq/yr are millions of tons of carbon equivalent GHG per year, with global warming potentials of methane, nitrous oxide and other GHG other than carbon dioxide, used as conversion coefficients for non-CO2 gases.

[3] For a review on carbon sequestration in terrestrial ecosystems, refer to http://csite.esd.ornl.gov.

Could and should agriculture modify its present land-use patterns and agricultural practices for the explicit purpose of reducing emissions while satisfying demand? The present paper, after appraising the current modeling efforts, proposes a methodology to evaluate marginal abatement in agriculture now and at some future dates in the medium to long run (2010 and 2030). It then presents and discusses some simulation results of an likely climate policy, represented by two carbon prices : 20 and 50 US $/tC-eq.

2. Existing approaches to the issue of agriculture and the greenhouse effect

Research on GHG abatement or sequestration options in agriculture stems from a need to evaluate and compare net abatement options of all emitting sectors. The issue is mainly tackled at two levels:

- globally in integrated assessment models (IAM) combining GHG emissions scenarios with models of impacts of climate change, and ensuring consistency on resources uses and availabilities. IAM are of two types (Dowlatabadi, 1994, IPCC 1996b):
  - economic optimisation, like general equilibrium models which take into account the supply/demand adjustment processes in a multi-sectoral economy, such as Markal and ProCAM (IPCC, 2001). Agriculture, a sector among others, is included with its emissions coefficients;
  - simulation, such as Image[4] (Alcamo et al., 1998), which considers the impact on production and on climate of expected trends of population evolution, economic growth, as well as changes in production and consumption patterns. These factors affect significantly the demand for agricultural products as well as supply reactions. The resulting response of agriculture does impact upon the climate, which in turn can lead to changes in demand for agricultural products and supply reactions, and so on. Price effects and other economic transmission mechanisms are however missing, the driving forces of the model lying in exogenous projections.
- at the plot level in crop growth models, such as Cropsyst, Epic or Stics[5], where agricultural practices are represented with the corresponding emissions, for diverse and locally specified soil and climate conditions, without the corresponding detailed costs information.

An hybrid type of models in which agriculture is considered specifically, is positioned between these two levels and draws on both. It addresses the issue of the leeway for GHG emissions mitigation provided by agricultural practices, through a thorough representation of production and technical choices as influenced by carbon price. Such models provide a consistency framework for building marginal abatement costs curves. Their development involves processing data collected or simulated at the plot level, the related emission and abatement indicators, a detailed representation of the production systems (objectives, constraints and context) and the decision making process at the farm level. The price of carbon is included among the costs that may induce changes in land uses and technological choices (see Alig et al., 2001; Chang et al., 2002; among works of Dr Bruce McCarl from Texas A&M University[6]).

The detailed information on agronomic and farming systems required by this type of models is not available worldwide. Besides, hybrid models are site- or country-specific, which makes

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[4] www.rivm.nl/image

[5] Cropsyst (www.bsyse.wsu.edu/cropsyst), Stics (www.inra.fr), Epic (www.brc.tamus.edu/epic).

[6] http://agecon.tamu.edu/faculty/mccarl.

the comparison and the aggregation of results difficult. A complementary type of model is therefore proposed with Agripol, maintaining a similar approach of representing farmers and herders behaviours. Its particularity lies in the use of a single framework worldwide, exploiting and extrapolating available data, and incorporating risk associated with changes in agricultural practices, to allow the assessment of possible responses to carbon prices.

3. Agripol, a sectoral model to assess possible responses of agriculture to carbon pricing

The purpose of Agripol is to process available information on agricultural practices and constraints affecting production, to determine the sectoral response to a carbon price. Such incentive stands as a proxy a hypothetical climate policy willing to induce agriculture contributing to mitigation efforts. The approach proposed aims at being consistent across world regions and sub-regions and across activities to allow for comparisons of abatement potentials with other sectors.

Agripol is a static economic optimisation model that runs for each of 40 world sub-regions. On the basis of estimations from a IAM Image Business-As-Usual (BAU) scenario that provides by 2030 a coherent framework on general trends including population, economic growth and climate evolution, the model considers a double constraint of production levels and of resources.

In its present version, Agripol accounts for 8 major non-CO_2 GHG emitting activities[7], and only considers agricultural land uses. Analysing possibilities for policy-induced abatement in the agricultural sector implies to look for economically feasible processes where a lower level of emission can be attained using a different management of cropping systems, animal feeding, irrigation, or fertilizer dosing. The model focuses on emitting activities rather than on physical emission processes.

For each commodity the representative[8] agent whose choice of practices is modelled, portrays the “regional commodity producers” which maximise their net revenue from the agricultural activities and minimise the risk associated with this choice, according to the attitude prevalent amongst commodity producers.

In vectorial terms, this core specification of the model can be summarised in:

$$\text{MAX } \mathrm{Re}venue - \frac{1}{2} a.s^{2} - CC$$

subject to :

$$\sum_{act}\sum_{tech} Coeff_{act,tech,res} \leq \mathrm{Re}sources_{res}(BAUscenario \text{ and } othersources)$$

$$\sum_{act}\sum_{tech} Emissions_{act,tech} \geq 0$$

$$\sum_{tech} Yield_{act,tech} = Expected\_production_{act}(BAUscenario)$$

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[7] Dairy livestock producing milk and emitting CH_4 and N_2O, non-dairy livestock producing beef and emitting CH_4 and N_2O, rice production as a source of CH_4, three N_2O emitting crop productions, pastures or grassland management. World wide livestock productions, rice plantations and other fertilised crops, for respectively 26%, 7% and 6% of land-use emissions (IPCC, 2001).

[8] For each commodity and region, the risk aversion coefficient allows to reproduce a variability in farmers' choices of practices that was assumed to be a proxy for diversity in farmers' population and attitudes.

where '*Revenue*' is the outcome of: income less fixed and variable costs plus subsidies and other revenues; 'σ^2' the expected possible deviation of income; 'α' the risk aversion coefficient[9] exogenously determined; and 'CC' the carbon price. 'Coeff' is the matrix of technical coefficient, and the vector '*Resources*' accounts for endowments. Indices 'act', 'tech' and 'res', respectively stand for agricultural activities, practices, and resources.

Risk is represented through the variance of gross margins traducing uncertainty linked to both climate and choices of practices. Co-variances are assumed to be zero. Parameter α also allows the calibration of the model to fit with the estimations from the BAU scenario on land use and with expert sayings on the diversity of technological choice for each commodity in each region. The corresponding choice of activity intensity at each technical level is a linear function of C cost and non linear of risk, as in standard optimisation models with risk (Gérard et al., 2000).

Constraints refer to resource endowments:
- land (arable, grazing or forest);
- inputs (for crop cultivations);
- skilled labour, that may become a limiting factor when activities become technically more sophisticated;
- unskilled labour;
- capital that may be a limiting factor when heavy investments are required;
- and two endogenously available resources: feed for animal (livestock activities), of which cereals whose production requires corresponding areas to be reassessed, and grassland.

Only land availability is currently binding the model, because of the lack of precise information on most of the resources. The equations on the other resources are used for "metering", accounting for the quantity of resources required, to eventually check consistency with other models' results.

Data on average GHG emissions by activity was firstly looked for in IPCC Guidelines for National Inventories, the reference manual for Agriculture. The impact of technological choices on emissions levels was then investigated among experts under the umbrella of the European Climate Change Programme (ECCP) working group Agriculture[10] and of the non-CO_2 GHG network[11], and to a lesser extent, of the OECD group on soil carbon indicators and the FAO initiatives (experts consultation, forum) on carbon sequestration[12]. For each activity, energy consumption is also considered, as an indirect CO_2 source, so as to relativise the attractiveness of processes that would be CH_4- or N_2O-saving but also energy-intensive. Extrapolation was worked out from data available in published and discussed reports or recomputed from own local sources. Economic data are composed of operational costs and structural costs, prices that multiply yields (that also multiply yields variances to give income variances) and additional revenues and subsidies accounting for agricultural policies.

The simulation entirely lies on responses to the carbon price. C price directly affects the variable costs, it multiplies emission levels by activity and technical level, thus modifying net economic margins. It also affects indirectly fixed costs, when the less emitting practices require capital investments. When the carbon price is modified: within each activity,

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[9] α=0 if the farmers of a given commodity are risk takers, α>0 if risk averse.

10 http://www.europa.eu.int/comm/environment/climat/eccp.htm
http://europa.eu.int/comm/environment/enveco/climate_change/agriculture.pdf

[11] Documents are available on the Energy Modelling Forum website: http://www.stanford.edu/group/EMF.

[12] Respectively, http://www.oecd.org/agr/env/indicators.htm and http://www.fao.org/landandwater/agll/lada/emailconf.stm.

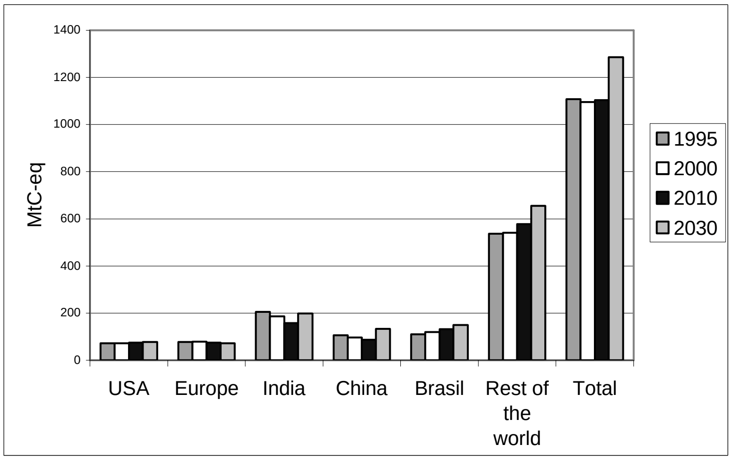
substitutions take place between practices, such substitutions may modify land requirements for the different activities and grassland. The model allows to incorporate forest and grassland into arable land, explicitly considering substitutions in land uses.

4. Simulation results : abatement potentials in agriculture

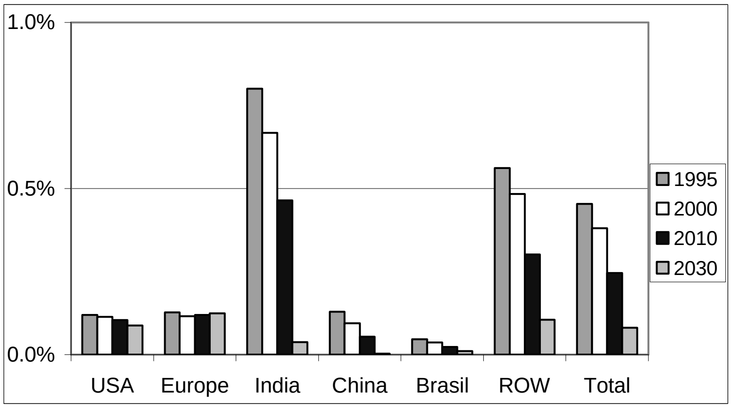
For years 1995, 2000, 2010 and 2030, simulations are run for the BAU scenario and for two non-zero carbon prices: 20 and 50 US$/tC-eq.

For the BAU scenario in 1995, the level of emissions estimated by the model for the 8 agricultural activities considered is of 1.1 GtC-eq.(Graph 1). Five regions account for around 50 % of them: Europe, USA, India, China and Brazil. In Europe by 2030, emissions decrease thanks to a combination of technical improvement and lower food demand as a consequence of a decreasing population. USA slightly increases its emissions throughout the period. In the case of India and China, available technical progress could allow a decrease in emissions, even with a significant population growth. However by 2030, the foreseeable increase of this population growth and of changes in consumption patterns along with economic growth, imply more land dedicated to higher emitting activities (namely more animals). Currently available technology might not be sufficient to meet the increasing food demand, in particular for livestock products. Brazil will increase the land dedicated to agriculture and thus its emissions. In the "rest of the world" (ROW), the increase in non-CO_2 GHG total emissions results from a combination of population growth, increased food demand, and a lack of possibilities to adopt improved technical alternatives.

Graph1: total emission from the 8 agricultural activities considered in Agripol.

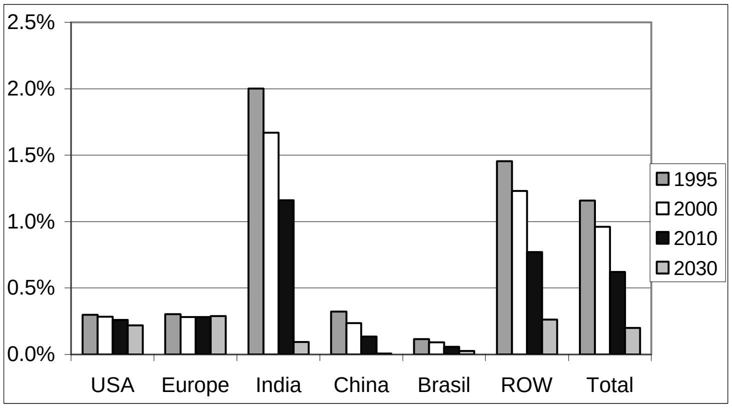


Graph 2: emissions abatement obtained in agriculture with a 20 US$/tC-eq



In the 20 $/tC-eq simulation the potential for abatement appears lowly exploited in percentage terms. Nevertheless, it implies total abatement opportunities ranging from 5 MtC-eq in 1995 to 1,5 MtC-eq in 2030.

Graph 3: emissions abatement obtained in agriculture with a 50 US$/tC-eq.



Potentials are more deeply exploited when applying a C price of 50 $/tC-eq: 1.2% (12.8 MtC-eq) in 1995, 0.2% (2.6 MtC-eq) in 2030.

Two issues limit the relevance of the results. First, farmers and herders bear the whole C price and do not transfer it to consumer prices. Consequently, the expected demand for agricultural goods has been considered inelastic to prices in each region, implying that consumers do not modify their consumption patterns. Second, agricultural sinks are not considered, especially the soils where carbon could be stocked as a function of the production practices chosen and thus increase income. Hence, further research is due to consider the explicit consideration of possible changes in demand for agricultural product, for instance by introducing sensibility of this demand to carbon price, thus relaxing the production constraint. A more comprehensive approach is also needed, that includes feedback effects of carbon pricing in agriculture due to possible leakage, and substitution effects, as well as a thorough representation of the sink capability offered by the sector.

5. Conclusions

The magnitude of abatement potential provided by the agricultural sector is low when compared with the total GHG emission reduction opportunities: 800 MtC for 20 $/tC-eq and 1,580 MtC for 50 $/tC-eq according to POLES 5 estimations for the year 2010[13].

Moreover, several concerns outside the scope of the proposed analysis, might advocate for not imposing a tax on non-CO_2 GHG emission from the agricultural sector. The first is that monitoring and evaluating the “real” abatement at the plot level will be haphazardly. Second, imposing a C price may affect the profitability of agriculture. Many farmers in the world may not be able to cover production costs and the taxes associated with non-CO_2 GHG emissions. If this in the case in developing countries where more than 60% of the population is rural and where the other sectors in the economy offer few or no opportunities, implementing a C policy in agriculture might produce exclusion, pushing the affected population to an uncontrolled use of natural resources.

It might be necessary to elaborate more viable and sector-specific climate policies, like subsidizing the implementation of less emitting practices. Knowing that in OECD countries agricultural subsidies total 1 billion US$ a day, part of this amount could be directly linked with the adoption of less emitting practices worldwide and thus tap deeper into the abatement potential of the sector .

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