

The Effectiveness, Efficiency and Equity of Market-based and Voluntary Measures to Mitigate Greenhouse Gas Emissions from the Agri-food Sector¹

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- ⇒ Agriculture accounts for 13 per cent of global GHG emissions. This rises to approximately 30 per cent if land clearance for farming, agrochemical production and trade in agricultural and food products are attributed to the sector.
- ⇒ Market based mechanisms (carbon tax, cap and trade, payment for environmental services) and voluntary mitigation measures (carbon labelling and food miles) are reviewed for their effectiveness (if they reduce emissions), efficiency (the costs of the measures) and equity (fairness to suppliers).
- ⇒ Measures to reduce agricultural emissions are limited in their effectiveness and efficiency by the technical difficulty and high costs of measuring, reporting and verification. However, pricing carbon would be effective in internalizing negative externalities in the transport, processing, retail and consumer purchase and preparation of food.
- ⇒ The GTAP model is used to illustrate that a US\$40 carbon tax implemented in the EU would have little negative impact on developing country exporters of agricultural products due to their low carbon intensity.
- ⇒ Carbon labelling and food miles initiatives are likely to be ineffective, inefficient and unfair to developing country exporters.

A. Introduction

Most scientists agree that human activity that releases carbon dioxide (CO₂) and other greenhouse gases (GHGs) into the atmosphere is the dominant cause of climate change. The current concentration of CO₂ in the atmosphere is around 380 parts per million (ppm), up from 280 ppm in pre-industrial times. The Intergovernmental Panel on Climate Change (IPCC) considers it will be necessary to stabilize global GHGs at a maximum level of 450 ppm CO₂ equivalent (CO₂ eq) to avoid a temperature rise of more than 2°C. This would require a reduction in global emissions of 80 per cent below 2000 levels by 2050 (IPCC, 2007). However, global emissions increased by 70 per cent between 1970 and 2004, and are still growing.

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Some climate models predict that emissions growth without constraints could result in rises in temperature of between 4° and 5°C on average by 2060. This could mask far higher temperature rises (10°-15°C) in many areas, including in lower latitudes and the Arctic (Met Office, 2009). As pointed out by Stern (2008: 57), the human effects “could be catastrophic, but are currently very hard to capture with current models as temperatures would be so far outside human experience.”

According to the IPCC (2007b), agriculture accounts for about 13 per cent of total GHG emissions. This figure rises to 30–40 per cent if deforestation through land clearance for agriculture and trade in agri-products are included. Agricultural emissions grew by 17 per cent during the period 1990–2005. The value of trade in agricultural products grew by 100 per cent over a similar period (1990–2007) (WTO, 2008). Production of and trade in food is projected to continue to increase in response to population growth and changing diets, in particular towards greater consumption of ruminant meats (i.e. beef, veal and lamb) (UNFCCC, 2008). Yet, despite their large contribution to climate change, emissions from agriculture are not included in reduction commitments under the Kyoto Protocol or the EU’s Emissions Trading System (ETS). It is therefore important to examine the potential economic instruments that could help reduce emissions in the agricultural sector as well as in the rest of the agri-food supply chain.

Stern (2008) cites three criteria for the design of climate change policies: effectiveness (i.e. resulting in emission reductions), efficiency (i.e. policies that cost little to implement) and equity (i.e. policies that are not regressive, and do not distort trade or have an undue impact on competitiveness). This paper examines the effectiveness, efficiency and equity of market-based instruments (MBIs)³ for a climate change mitigation in the agri-food sector. These instruments include carbon taxes, emissions trading schemes, payment for environmental services (PES) schemes, border tax adjustment measures, carbon food miles, accounting and labelling.

The scope of this paper does not include support for research and development (R&D) or subsidies for clean energy, although their importance in contributing to climate change mitigation in the agricultural and food retail sector is acknowledged. In addition, the paper does not examine adaptation measures.

B. Impact of the agri-food sector on climate change

1. Contribution to climate change

Agricultural emissions account for 13 per cent of total GHG emissions, or between 5 and 6 gigatons (Gts) of CO₂ equivalents (CO₂ eq),⁴ and they are predicted to rise by almost 40 per cent by 2030 (Smith et al., 2007). This is largely due to increased demand from a growing population and to a greater demand for ruminant meats. Of these emissions, methane (CH₄) accounts for 3.3 Gts equivalent and nitrous oxide (N₂O) for 2.8 Gts equivalent annually. Net emissions of CO₂ are just 0.04 Gts of CO₂ eq per year.⁵ Agriculture emits over half of the world’s emissions of nitrous oxide and methane (figure 1). These are the most potent GHGs: N₂O traps 260 times more heat than CO₂, and CH₄ traps 21 times more heat.

³ In this paper, market-based instruments include carbon taxes and offsets, although, strictly speaking, these are fiscal instruments.

⁴ Carbon dioxide equivalent expresses the amount of global warming by GHGs normalized to the equivalent amount of CO₂ that would have the same global warming potential (GWP). The major examples of such GHGs are methane and nitrous oxide.

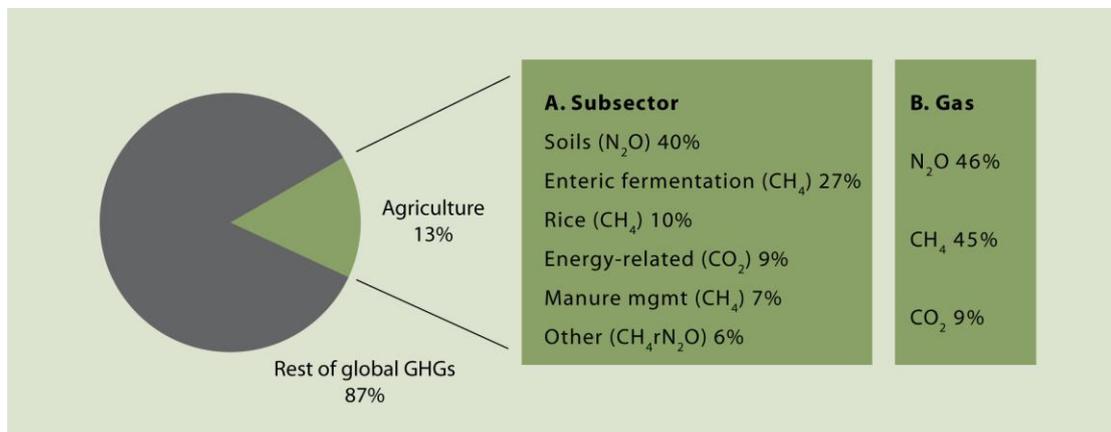
⁵ The net flux of CO₂ between agricultural land and the atmosphere (released from microbial decay and burning of plant litter and organic matter in the soil) is approximately balanced (0.04 Gt of CO₂/yr). However, the emissions from fuel and electricity used in agriculture are included in other sectors (transport and building) (Smith et al., 2007).

Nitrous oxide is emitted mainly from fertilizer and manure applications to soils, while methane is emitted mainly in livestock production (fermentation in digestion), rice production and manure handling. Emissions from these sources are also projected to rise.

Emissions from the agricultural sector rise further, to between a quarter and a third of total GHGs, if the estimated emissions from deforestation in developing countries (where agriculture is the leading cause of deforestation) are added. However, the IPCC does not attribute these emissions to the agricultural sector.

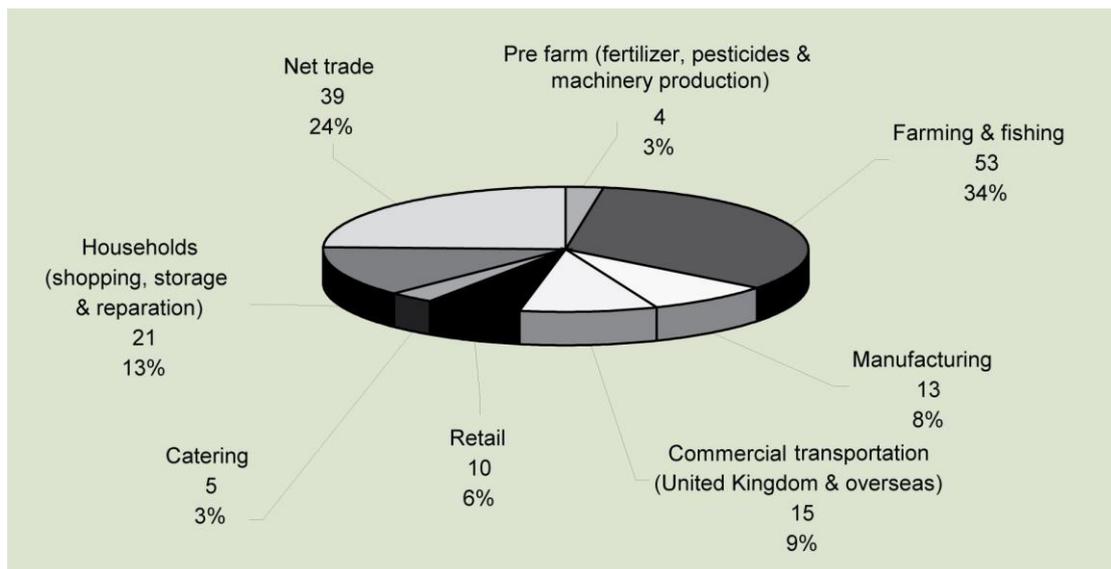
Transport, processing, retailing and household consumption of food adds further emissions associated with agriculture. Swaminathan and Sukalac (2004, cited in Bernstein et al., 2007) report, for example, that the fertilizer industry accounts for about 1.2 per cent of world energy consumption and is responsible for about the same share of global GHG emissions. In the United Kingdom, processing, transport, retail and households accounted for two thirds of total GHG emissions along the food supply chain in 2006, while agriculture accounted for most of the remainder (figure 2).

Figure 1. Greenhouse gas emissions from agriculture



Source: Worldwatch Institute, 2009, citing EPA, 2004.

Figure 2. Greenhouse gas emissions from the food chain in the United Kingdom, 2006 (millions of tons and percentage)



Source: DEFRA, 2008.

In agricultural production, food products vary in the intensity of their emissions. For example, around 50 per cent of GHG emissions in Dutch food come from dairy and meat production

(Kramer et al., 1999, cited in Garnett, 2008), whereas these two categories of food contribute 8 per cent of the United Kingdom's total GHG emissions.

2. Mitigation potential of the agri-food sector

The agricultural sector has the potential to mitigate climate change mainly by increasing the carbon sequestration rate (i.e. rate at which carbon is stored in the soil), and to a lesser degree, through the reduction of some GHG emissions (principally N₂O and CH₄) (Smith et al., 2007). Across the rest of the agri-food supply chain, mitigation can be achieved through carbon emission reductions.

The technical mitigation potential of agriculture is around 6 Gt CO₂-eq per year by 2030. The economic mitigation potential (i.e. the amount of GHG mitigation that is cost-effective for a given carbon price) is considerably lower: between 1 and 4 Gt CO₂-eq per year. The level achievable depends on the level of the carbon price and the effectiveness of policy instruments: the higher the carbon price, the greater is the potential for mitigation. Barker et al. (2007) estimate that 89 per cent of the potential for GHG mitigation in the agricultural sector could be achieved through carbon sequestration. Most of this potential (70 per cent) lies in developing countries. Improved grazing and cropland management and agroforestry offer the highest potential for carbon sequestration (UNFCCC, 2008a; FAO, 2007), while the remaining 11 per cent of the mitigation potential is achievable through reductions in nitrous oxide and methane emissions.

Table 1. Selected mitigation options in agriculture and the agri-food sector

Sector	Part of agri-food supply chain	Selected mitigation options
Agriculture	Food production	Improved cropping and grazing land management to increase carbon storage Improved rice cultivation techniques and livestock to reduce methane emissions Improved nitrogen fertilizer application techniques to reduce nitrous oxide emissions
Energy	Energy for fertilizer production, food processing, tractors, consumer and retailers use, transport	Improved supply and distribution efficiency, fuel switching, nuclear and renewable energy, carbon capture and storage
Industry	Fertilizer production Food processing (e.g. corn wet milling)	Energy efficiency improvement and retrofit
Building	Lighting, cold storage in warehouses and retail outlets Consumer food preparation	Efficient lighting, more efficient electrical appliances and heating and cooling devices, improved cooking stoves
Transport	Food logistics Consumer travel to shops	More fuel-efficient vehicles More efficient aircraft

Source: Adapted from IPCC, 2007c and Bernstein et al., 2007.

Niggli et al. (2008a and 2009) see strong potential for climate change mitigation in organic agriculture, for instance, and highlight added benefits such as conserving agricultural biodiversity, reducing environmental degradation and integrating farmers into high value food chains.⁶ Similarly, the UNFCCC (2008a) emphasizes that mitigation options offer “synergies for improved sustainability”. However, the adoption of sustainable agricultural systems, such as organic farming, depends on supportive policies (Twarog, 2006) and the internalization of environmental costs across the agricultural sector in order to improve the economic incentives for farmers to adopt more sustainable practices.⁷

The UNFCCC (2009a: 8) cautions that, given the increasing population and the growing demand for ruminant meat and dairy products, the sector is severely constrained in its ability to achieve emissions savings. It concludes that “...it would (therefore) be reasonable to expect emissions reductions in terms of improvements in efficiency rather than absolute GHG emissions.” The IPCC also makes recommendations for reducing GHG emissions in energy, transport, building and industry. Those relevant to reducing emissions across the whole agri-food supply chain are summarized in table 1.

3. Policy measures for emissions mitigation in the agri-food sector and carbon storage in agriculture

a) Types of measures

A number of policy instruments can be used to mitigate emissions by the agri-food sector and to store carbon in agriculture. These include: regulation, market-based instruments (cap and trade, taxes), agricultural cross-compliance programmes,⁸ information provision and voluntary measures, subsidies, and support to R&D and technology transfer. Non-climate policies also have an impact on emissions from agricultural activities, including, for example, the European Union (EU) Common Agricultural Policy (CAP) and the EU Nitrates Directive (UNFCCC, 2009a).

b) Design criteria

The IMF (2008) and Stern (2008) have identified several criteria for designing successful policies to mitigate climate change. These include (italics added):

- i) To be *effective*, policies must raise the prices of GHGs to reflect the environmental damage from emissions. Higher GHG prices would discourage the production and consumption of GHG-intensive products and services and encourage the development of new, low-emission technologies;
- ii) To ensure policy objectives are achieved at the *lowest cost*, mitigation policies must be applied across all GHGs, firms, countries, sectors and time periods;
- iii) Mitigation policies must address *distributional impacts* across firms, income groups and generations, for reasons of fairness and to ensure that policies are politically viable;
- iv) Mitigation policies must be *flexible* enough to adapt to changing economic conditions and scientific information about climate change; and

⁶ For more information on this, see the commentary by Niggli in this Review.

⁷ Several general principles can be applied to help growers select sustainable management practices: (i) selection of species and varieties that are well suited to the site and to conditions on the farm; (ii) diversification of crops (including livestock) and cultural practices to enhance the biological and economic stability of the farm; (iii) management of the soil to enhance and protect soil quality; (iv) efficient and humane use of inputs; and (v) consideration of farmers' goals and lifestyle choices. Examples of some of the key specific strategies of sustainable agriculture are: organic farming, low external input sustainable agriculture (LEISA), integrated pest management, integrated production (IP) and conservation tillage.

⁸ Under the 2003 EU CAP reform, farm support shifted from price support to direct payments to farmers. Payments are contingent, or “cross compliant”, on farmers respecting environmental requirements set at EU and national levels.

- v) Mitigation policies must be *enforceable* and remain in place in order to induce the needed behavioural change.

c) Issues for consideration

According to UNFCCC (2008a), the adoption of any policy or measure to reduce GHG emissions in the agricultural sector would need to take account of the following issues:

- i) Increasing world population, which is forecast to reach 8 billion by 2030 and 9–9.5 billion in the second part of this century;
- ii) The population growth will translate into higher demand for food, particularly for animal products. Developing countries are likely to account for a large proportion of this new demand, due to higher incomes which will induce changes in dietary habits;
- iii) Three quarters of agricultural emissions are in developing regions;
- iv) Continued pressure for land-use change, mainly in developing countries, resulting in the conversion of forest lands to agricultural lands, would cause greater carbon losses due to deforestation;
- v) Non-climate-related policies implemented by countries, which could affect the levels of GHG emissions from agriculture;
- vi) Continued pressure on agricultural land for the production of biofuel crops;
- vii) Mitigation efforts in agriculture, which could contribute to sustainable development; and
- viii) Security and poverty alleviation efforts.

d) Market-based instruments and voluntary measures

Policymakers increasingly favour market-based instruments (price incentives) over compulsory measures, such as regulation, as a way to address market failures.

This paper examines market-based instruments and voluntary measures for reducing emissions in the agri-food sector according to the criteria of effectiveness, efficiency and equity.

The analysis covers the following:

1. Cap-and-trade schemes and carbon taxes;
2. Border tax adjustments (BTAs);
3. Payments for environmental services (carbon sequestration);
4. Carbon labelling ; and
5. Food miles campaigns.

C. Emissions trading schemes and carbon taxes

1. Background

Emissions trading schemes and carbon taxes are the two main market-based instruments for pricing GHGs, in particular CO₂.

Under the Kyoto Protocol, a group of developed countries, known as Annex 1 countries, agreed to reduce emissions during the period 2008–2012 to 5 per cent below 1990 levels. Annex 1 countries can meet their emission reduction commitments by using the “flexible mechanisms” in the Protocol. These mechanisms include: Emissions trading, the Clean Development Mechanism (CDM) and Joint Implementation (JI).

A number of governments and municipal authorities have implemented emissions trading schemes, also referred to as cap-and-trade schemes. Under these schemes, governments set a limit (cap) on the amount of GHG emissions permitted by industry. Every large company is allocated a permit to release a set amount of GHGs, and companies can trade these permits. The most notable example of cap-and-trade schemes is the EU Emissions Trading System (ETS) and the scheme proposed by the Waxman Markey bill under review by the United States Senate.

Carbon taxes, an alternative instrument to cap and trade for reducing GHG emissions, have been introduced by a number of countries, including Costa Rica, Finland, France, the Netherlands, Norway and Sweden, and also by the Canadian province of British Columbia..

2. Effectiveness and efficiency

a) Carbon tax versus cap and trade

In theory, both cap and trade (with auctioned permits) and carbon taxes achieve a similar level of efficiency by reaching the abatement level target at a minimum cost (*Environmental Economics*, 2008; Viard, 2009). However, the two instruments differ in design. A cap-and-trade-scheme sets a limit (cap) on emission levels and allows the price of the emissions (in this case CO₂) to vary. A carbon tax, on the other hand, puts a price on emissions, but allows the emission levels to change. A carbon tax can be increased if the emission levels are still too high, whereas permits are allocated for the duration of a cap-and-trade scheme.

The IMF (2008) cites three main advantages that carbon taxes have over cap-and-trade schemes: greater price stability, greater flexibility as economic conditions change, and a larger stream of revenue that can be used to enhance efficiency and equity (see also WTO/UNEP, 2009; and Blandford and Josling, 2009 for further discussion).

b) Inclusion of agriculture in cap and trade

Agriculture is not part of the ETS or the United States Cap and Trade Climate Bill.⁹ The main obstacle to including the agricultural sector in a future cap-and-trade scheme is establishing a cost-effective system of what the UNFCCC (2008a) terms “monitoring, reporting and verification” (MRV).

Establishing reporting procedures for emission reductions under a national GHG inventory framework requires a reliable data set based on different parameters. However, such data may be subject to discrepancies or they may be unavailable (UNFCCC, 2008a). It is particularly difficult to estimate emission reductions and carbon sequestration from agriculture because of the high degree of spatial (soils and environments) and temporal (climatic) variability. Moreover, full accounting is costly and complex (Paustian et al., 2004).

DEFRA (2009) highlights the high transaction costs that smaller farmers would face in trading emission permits. Unless farmers can group together to share these costs, it is unlikely that individual farmers will find it economical to trade.

c) Need for upstream pricing instruments

An important consideration in designing a carbon reduction policy is the issue of obligation (i.e. where a tax or quantitative restriction is imposed). A downstream trading programme like the EU-ETS, for example, currently covers electricity and large industrial emitters, and accounts for only 50 per cent of total CO₂ emissions. It therefore precludes other potentially low-cost abatement opportunities.

Upstream programmes, on the other hand, which price the externality at the source of energy production, capture a far higher proportion of emissions. If a tax or trading system was applied upstream in the fossil fuel supply chain (e.g. petroleum refineries and coal producers), the price of carbon would be passed on to the fossil fuel price, and ultimately to the price of electricity and other energy-intensive products. Such a system would also be easier to administer (IMF, 2008).

Notwithstanding the high non-CO₂ GHG emissions from agriculture, a global carbon price applied upstream would obviate the need for MRV, as all *carbon-related* environmental costs

⁹ Apart from agriculture, the other non-ETS emission sources include transport, households, services, smaller industrial installations and waste. Agriculture represents up to 40 per cent of emissions by the non-ETS sector (Breen, Donnellan and Hanrahan, 2009).

would be immediately “internalized” in the supply chain. The MRV issue thus underlines the importance of applying a carbon pricing instrument as far upstream as possible.

d) Production-based accounting

Global upstream pricing instruments also help resolve the problem of countries’ GHG emissions being measured by production rather than consumption. Accounting for GHGs based on location of production creates a “misleading and partial basis” to inform policy (Helm et al., 2007). A country could have a very low production of GHGs but at the same time have a high consumption level; it could produce low GHG-intensive goods, but import and consume high GHG-intensive goods. The shift in production from Europe and the United States to Asia, and the consequent increase in emissions in Asia, suggests that this effect might be considerable. Thus, emerging Asian economies might argue that although they produce high emissions, these are on behalf of consumers in developed countries, and that therefore the consumers should pay for the relevant reductions. In this way, the consumer, not the producer, is the polluter (Helm, Smale and Philips, 2007). An upstream carbon price would feed through to the consumer to internalize pollution costs.

With respect to the agricultural sector, carbon pricing upstream would help raise the price of both fuel and chemical inputs, resulting in reduced tillage and improved residue management. These are both important outcomes in reducing nitrous oxide emissions and sequestering carbon. Transport, retail and consumer use of fuel in the agri-food supply chain would also automatically internalize the environmental costs of CO₂ emissions. This would provide an incentive for emission-reducing behaviour throughout the supply chain and the wider economy.

e) Pricing non-carbon GHGs

It is desirable to incorporate all sources of GHGs into any mitigation programme. Nitrous oxide and methane, about 45 per cent of which are produced by agriculture, account for about one third of total GHGs. The costs of MRV could be a considerable obstacle to the adoption of a cap-and-trade system for agriculture (Breen, Donnellan and Hanrahan, 2009; DEFRA, 2009).

The IMF (2008) suggests that some sources of these gases (e.g. landfills, manure and soil management) be incorporated into an emissions offset programme. The onus would then be on the agency responsible for offsetting to demonstrate a credible system of MRV for crediting. As discussed in section E below, an emissions offsetting programme in agriculture would face high transaction costs due mainly to the need to profile heterogeneous land types and farmers and to contract and monitor many different farmers.

f) Need for global implementation

Pricing carbon, be it through a tax or cap-and-trade scheme, is most efficient if it is implemented globally. Countries that do not have commitments, or at least do not implement emission reduction policies, are likely to have a competitive advantage over those that do. Production will therefore “leak” or relocate to countries that do not make GHG-reduction commitments. Estimates of leakage are uncertain, but may range from 5 to 20 per cent (IPCC, 2007c: 12) of the reduction in emissions of the mitigating countries.

The extent to which exporting countries without commitments will have a competitive advantage in agricultural products over those countries with commitments depends on three factors:

- i) The severity of the emission reduction commitments in developed countries;
- ii) The ability to substitute alternative fuels in industries where emission reduction policies are implemented; and
- iii) The GHG intensity of production in each country, which depends largely on the energy use and mix of industries in each country.

g) Consumption tax

A national tax on consumption could be used to raise the price of GHG-intensive products like beef and dairy products. However, consumers in export markets would continue to demand these products in the same quantities. The incentives (i.e. prices) for domestic farmers would thus not change very much, and consequently the impact of a domestic consumption tax would be minimal (Breen, Donnellan and Hanrahan, 2009).

Furthermore, to the extent that it might discourage production, a uniform tax would be a blunt instrument if it did not take into account differences in emissions per unit of output at the farm level, and therefore failed to encourage innovation at that level.

3. Equity

a) Distributional impacts

Pricing carbon through cap and trade and taxation would increase the prices of goods and services according to their carbon “intensity”. This could have negative impacts on lower income groups that spend a large proportion of their total income on fuel products and services, like heating and transport.¹⁰ However, proponents of carbon taxes argue that equity issues can be addressed by reducing other taxes paid by low-income groups, for example on employment and income, or by setting up dividend funds for consumers (Hansen, 2009).

b) The carbon intensity of agriculture

In almost all countries, agriculture as a sector produces more value per unit of carbon input than the manufacturing and services sectors. This means that agriculture is less carbon-intensive per unit value of output than manufactured goods and services. The services sector, which includes transport, tends to be the most carbon-intensive.

Within the agricultural sector, GHG emissions per unit of output vary greatly across countries (see table 2). The variation reflects the composition of products. For example, production of flowers and vegetables under heated greenhouses is energy-intensive, whereas cereal production is not, at least relative to heated greenhouse production. In low-income countries, where wages are low, labour is used instead of fuel-driven equipment, fertilizers and pesticides. In many poor countries draft animals are used instead of tractors to cultivate fields. Thus the carbon intensity of such operations is low.

Several developing and transition economies such as China, the Russian Federation and Turkey, have output well below the global average of \$8,000 per ton of CO₂ emissions, but many more have output-to-emissions ratios well above the average. This implies that the former countries have low carbon-intensive agriculture, and may have a competitive advantage should global measures to reduce GHG emissions be implemented.

c) Impacts on developing-country agricultural exports

The effects of a carbon tax or similar mitigation policies in Annex 1 countries on developing-country agricultural production and exports are likely to be relatively small. The potential impacts can be estimated using a suitable general equilibrium model, such as GTAP, in which the sectors are linked according to national input-output tables and countries are linked through international trade.¹¹

¹⁰ In this regard, see also the commentary by Ackerman in this Review.

¹¹ For a description of the GTAP model, see Hertel, 1997.

**Table 2. Carbon intensity of selected countries, by sector:
value of output per ton of CO2 (\$ thousand)**

	Agriculture	Manufacturing	Services
Developed economies			
European Union	8.4	7.5	2.1
United States	7.0	5.5	3.1
Japan	24.8	13.6	6.5
Canada	9.5	3.5	2.3
Australia	7.9	2.6	1.5
New Zealand	21.9	4.5	2.8
Korea, Republic of	6.6	6.7	1.9
Developing and transition economies			
Russian Federation	2.4	1.2	0.3
Turkey	3.4	3.0	1.2
China	4.1	2.1	0.5
Zimbabwe	4.7	2.9	0.8
Thailand	4.9	2.4	0.9
Tunisia	5.0	3.7	1.4
Brazil	5.1	3.4	3.7
Argentina	6.1	2.7	4.4
South Africa	6.4	1.5	0.5
Malaysia	6.4	4.0	1.0
Colombia	8.4	1.6	3.1
Viet Nam	10.8	1.7	1.0
Indonesia	11.0	1.3	0.8
Chile	13.1	2.0	2.5
Taiwan Prov. of China	15.0	6.3	1.9
Bangladesh	15.5	2.4	2.8
Uruguay	16.7	6.9	8.9
Philippines	19.3	5.0	1.2
Venezuela, Bolivarian Rep. of	24.9	1.0	2.2
Peru	29.8	4.5	3.7
Mexico	30.7	7.3	0.8
India	35.1	1.7	0.6
Morocco	41.7	6.3	1.6
Zambia	69.3	3.4	4.3
Sri Lanka	69.3	8.9	1.1

Mozambique	94.3	8.9	4.2
Botswana	97.3	31.6	2.4
Uganda	195.4	6.0	1.8
Malawi	231.2	14.0	1.7
Tanzania, United Rep. of	239.2	8.2	3.7
Madagascar	354.6	28.7	1.5
World ^a	8.2	4.2	2.4

Source: Derived from Global Trade Analysis Project (GTAP) database, Center for Global Trade Analysis, Purdue University; and Lee, 2002.

^a World includes countries in addition to those listed in this table.

GTAP is designed to show the potential impacts on production, consumption and trade in a range of sectors in response to changes in various taxes. In this application, a tax on the production of petroleum and coal products according to the carbon content is simulated to assess the likely impact. The additional tax works its way downstream through the economy to the final consumer. This leads to a fall in consumption, especially of domestically produced carbon-intensive goods. However, consumers would be expected to demand more imported goods from countries which do not impose a similar tax. On the other hand, a simulation of a \$30 per ton carbon tax (the approximate price in the EU-ETS prior to the global financial crisis) on EU GHG emissions leads to no significant change in developing countries' agricultural exports. This is because land previously used for cereal and oilseed production in the EU is switched to the production of other crops and livestock, displacing some of the imports from developing countries.¹²

Table 3 shows the estimated change in agricultural exports from developing countries by sector as a result of a hypothetical carbon tax on EU emissions. This simulation excludes taxes on methane emissions, and also ignores agriculture's potential for bio-sequestration.

Table 3. Percentage changes in value of developing-country agricultural exports following a hypothetical \$30/t carbon tax on EU emissions (\$ thousand)

	Rice	Wheat	Other cereals	Oilseeds and fats	Other crops	Livestock	Meat	Other processed	Total, including non agriculture
Selected LDCs ^a	0.30	0.51	0.30	0.36	0.23	0.21	0.23	-0.19	-0.03
China	-0.11	0.32	0.18	-0.04	-0.07	0.07	0.12	-0.06	0.03
India	-0.35	-0.27	-0.03	-0.06	-0.30	-0.24	-0.62	-0.31	0.09
Brazil	-0.35	0.10	0.20	-0.23	-0.11	-0.02	-0.42	-0.21	0.04
South-East Asia	-0.33	-0.12	0.12	0.03	-0.13	0.02	-0.25	-0.08	0.08
West Asia	-0.06	0.15	0.05	0.20	-0.22	-0.18	-0.04	-0.17	-0.03
Central and Eastern Europe	-0.54	-0.17	0.10	-0.55	-0.55	-0.46	-1.36	-0.57	0.96

¹² Author's estimates using the GTAP version 7 database (Dimaranan, 2006). The estimates apply to a 2005 base period and assume no technological improvements.

Central America	-0.21	-0.12	0.12	-0.13	-0.15	-0.02	-0.23	-0.15	0.05
Mercosur	-0.24	0.09	0.12	-0.07	-0.19	-0.12	-0.63	-0.28	0.06
Andean Community	0.06	0.18	0.27	0.03	-0.20	0.05	-0.19	-0.21	0.08
North Africa	0.23	1.62	0.51	0.24	0.01	0.10	0.31	-0.24	-0.06
West Africa	1.18	2.92	0.49	1.04	1.14	0.18	2.07	0.27	-0.03
Central and East Africa	0.13	0.59	0.24	0.09	-0.14	-0.28	-0.31	-0.43	0.00
Southern Africa	-0.33	0.29	0.06	-0.10	-0.36	-0.05	-0.76	-0.38	0.04
Rest of the World ^b	0.06	0.81	0.24	0.09	0.08	0.25	-0.03	-0.08	0.02

Source: GTAP simulation.

^a The selected least developed countries (LDCs) are: Afghanistan, Angola, Bangladesh, Bhutan, Cambodia, Democratic Republic of the Congo, Madagascar, Malawi, Maldives, Mozambique, Nepal, Senegal, Uganda, United Republic of Tanzania and Zambia. Some LDCs are aggregated into other regions. Derived from Global Trade Analysis Project (GTAP) database, Center for Global Trade Analysis, Purdue University; and Lee, 2002.

^b Rest of the World includes countries in addition to those listed in this table.

Agriculture is not sufficiently energy-intensive for a carbon tax to make much of a difference to production and exports. The estimated fall in developing-country agricultural exports is \$220 million, mainly in crops other than cereals and processed crops.

There are winners and losers among exporters, depending on the composition of their exports. Changes in the terms of trade, especially in manufacturing and textiles, from the imposition of a carbon tax in the EU lead to welfare losses for developing countries estimated at \$3.7 billion. This includes a welfare loss of \$138 million per annum for selected LDCs specifically, indicating that a carbon tax in the EU may impose a burden on some of the poorest countries, even though there are no border taxes imposed on embedded carbon. Global welfare losses are estimated at \$17 billion per annum, borne mainly by the region imposing the tax. However, it is important to emphasize that the values of the damages avoided (i.e. the benefits of the policy) should be subtracted from these costs to derive the overall cost/benefit of the policy.

Some commentators believe that as the emission targets become more restrictive, a much larger carbon tax will be necessary. A simulation of a hypothetical tax of \$100 per ton leads to estimated losses in developing-country agricultural exports of \$1,414 million, well up from the \$220 million resulting from a \$30 per ton tax, but still only 0.04 per cent of annual exports. Once again, gains and losses would vary from country to country. A tax on carbon-intensive fuel in developed countries would reduce demand for that fuel and reduce its relative price in developing countries. This should lower transportation costs in favour of those remote from the major markets. However, a tax on shipping fuels would place the more distant suppliers at a disadvantage.

It is not clear to what extent agriculture would relocate in response to changes in the price of carbon. As noted, agriculture is not particularly energy-intensive, at least compared with industries such as aluminium, iron and steel and cement. As illustrated in table 3, developing countries with a large agricultural sector are therefore unlikely to gain much of a competitive advantage from a carbon tax in this respect. This is because their economies would not be much affected – directly or indirectly – by carbon reductions in developed countries. The carbon tax would mainly affect carbon-intensive industries rather than agriculture.

d) Non-carbon greenhouse gas emissions

Methane has received relatively little attention to date, with no applicable emissions trading scheme similar to that for carbon, but this may change. Any future methane taxes on beef and sheep meat in developed countries may give some developing countries (e.g. Argentina, Brazil and Uruguay) a competitive advantage. Proposals by the Governments of Denmark, Ireland and New Zealand for a methane tax¹³ met with a strong negative reaction from their domestic farm industries (*Times*, 10 March 2009) because of concerns over the potential loss of competitiveness. There is currently limited scope to reduce methane in production economically.¹⁴ Thus the likely response to a methane tax would be for consumers to substitute their consumption of beef and sheep meat with pig and poultry meat as well as with game such as venison. Australians see a potential market in kangaroo meat (Garnaut, 2008: 540). However, the substitution effects are estimated to be slight.

Garnaut (2008, table 22.3) reports that a \$40 per ton tax covering carbon and methane would add perhaps \$1 per kg, or 6 per cent, to the retail price of beef and veal. However, Jiang, Hanslow and Pearce (2009), using farm-level data to assess the potential impact at the farm level of an ETS that incorporates methane and nitrous oxide as well as carbon, conclude that an emissions tax (in Australian dollars) of A\$ 25/t CO₂-e would raise the costs to beef producers by 18 per cent and to sheep producers by 10 per cent. This would result in a 60 per cent fall in farm cash income for the average beef producer. Moreover, a tax of A\$ 50/t would lead to a fall in income of an estimated 125 per cent, resulting in a net loss for these farms.

The implications for beef- and sheep-producing developing countries are obvious: countries without methane reduction commitments would gain. This raises the issue of how to respond to a loss in competitiveness.

D. Border tax adjustments

1. Background

Under the Kyoto Protocol, producers in Annex 1 countries are committed to emissions reductions, while producers of energy-intensive products in non-Annex 1 countries do not make any such commitments. This policy has failed to curb emissions in fast-growing developing countries. It has also led to concerns about loss of competitiveness for countries not constrained by emissions reduction commitments.¹⁵ Some developed countries have therefore considered responding to measures that increase the cost of carbon pollution by imposing border taxes on imports from countries that do not implement similar emissions reduction policies.

There have been suggestions that the EU should impose carbon taxes on imports from the United States, and that the United States should levy similar taxes on imports from China. These policies are likely supported by domestic industries as well as environmentalists. To date, such calls have focused on energy-intensive products, particularly those that embody carbon, such as cars that contain aluminium, a light but energy-intensive metal. It is a logical extension to include methane emissions in border measures, in which case ruminant meat imports could receive more attention as well.

One approach for addressing the loss of competitiveness as an exporting country is to reduce taxes or grant, for free, a proportion of carbon credits to trade-exposed industries. These concessions need not involve full compensation, but should be limited to reflect the loss of competitiveness because of the absence of a tax in competing countries. A difficulty with this

¹³ For more information in this regard, see the commentary by Rae in this Review

¹⁴ Garnaut (2008) cites Beauchemin et al. (2008) as claiming a 20–40 per cent reduction in methane emissions through better nutrition, but these changes are not cost-effective.

¹⁵ For a full discussion of BTAs, “leakage” and competitiveness issues, see WTO-UNEP, 2009.

approach is that it would encourage intensive lobbying, with each industry claiming to be a special case deserving of special treatment.

2. Effectiveness and efficiency

Border tax adjustments are difficult to design because of the high costs of establishing the levels of carbon embedded in imported products. Regulators will also be exposed to domestic lobbying when setting tariffs or allocating permits to trade-exposed industries. BTAs may also lead to retaliation, particularly following the global financial crisis which has increased protectionist pressure by domestic producers. BTAs effectively shift the tax from the producer to the consumer. Moreover, they may fall foul of international trade agreements. In these respects, they are an imperfect solution to a market failure, namely the oversupply of GHGs.

3. Equity

Border tax adjustments would have a negative impact on developing countries, such as China, that export carbon-intensive products not currently subject to a carbon price. A border tax would discourage exports of such products. However, developing-country importers of carbon-intensive products would benefit from the lower prices in the world market.

A BTA would have a small efficiency effect, but the main effect would be distributional, as with any tax. In this case, the burden would fall on developing countries, while the beneficiaries would be the governments that impose the taxes. However, there would also be distributional effects within the importing country, with consumers bearing the additional burden. While it is possible to identify the distributional effects, whether these would be equitable would depend on the starting point. For example, it could be argued that an equitable outcome would require all consumers to contribute equally to reducing emissions, and that a border tax would move towards this. Given the various alternative criteria for assessing an equitable outcome, such discussions are difficult to resolve.

E. Payment for environmental services

1. Description

The primary output of agriculture is food and fibre, but there is also potential for it to deliver environmental services. These “joint outputs” of commodity production include biodiversity, carbon sequestration, landscape and soil conservation and watershed protection. The extent to which agriculture can provide these public goods depends to a large extent on the crops grown or livestock raised, and on the economic incentives available. To date, these incentives favour the production of conventional food and fibre in response to consumer demand and as a result of agricultural support policies. Since there are few, if any, incentives for farmers to supply environmental goods and services, these are undersupplied or not supplied at all. The aim of payment for environmental services (PES) programmes is to get the incentives right, so as to encourage farmers and other natural-resource managers to increase the provision of environmental public goods from land use (FAO, 2007).

PES programmes were initiated in the 1980s when the EU and the United States introduced agri-environmental schemes as a response to public concern over environmental degradation in agriculture. In the 1990s, PES programmes were introduced in developing countries, the most notable being payments for forest-based environmental services in Costa Rica and Mexico. Hundreds of PES schemes are now implemented in both developing and developed countries, mainly for forest-based services, primarily carbon sequestration, biodiversity conservation, watershed protection and landscape conservation. To date, relatively few of the programmes have targeted farmers in developing countries, particularly for carbon sequestration (FAO, 2007).

The demand for environmental services from agriculture is mainly channelled through governments and international agencies. However, the private sector's role is growing in importance through conservation contracts and organic certification schemes.

There are two main sources of payment for carbon sequestration from agriculture: the Clean Development Mechanism (CDM) and "voluntary" carbon markets (see table 4). The world's largest carbon market, the EUETS, does not sell or trade credits generated by carbon sequestration. This is due to uncertainty in the EU concerning the measurement and maintenance of carbon stocks sequestered in agricultural soils (Young et al., 2007).

Table 4. Summary of carbon market and eligibility for carbon sequestration and emissions reductions in agriculture

Type of carbon market	Value 2007 (\$ million)	Volume 2007 (MtCO ₂ -eq)	Carbon sequestration	Agriculture-related emissions reductions
Allowances EU ETS	50 000	2 100	None	None
Voluntary carbon market (Chicago Climate Exchange)	91	265	No till agriculture (\$34 m in 2006)	None
Project-based transactions CDM and JI	13 600	874	Forestry (1% limit) \$52 m max.	Methane capture (3% of market)

Source: Adapted from FAO, 2008; Capoor and Ambrosi, 2008.

The Clean Development Mechanism (CDM) allows developed countries the option of buying carbon "credits" (or "certified emission reductions (CERs)) from developing countries in place of making their own emission reductions. In 2006, developing countries sold \$5.2 billion worth of carbon offsets to Annex 1 countries under the CDM (Hamilton et al., 2007). However, CDM rules restrict the type and amount of carbon emission reduction credits that can be obtained from carbon sequestration. Only afforestation and reforestation are allowed, and these are limited to 1 per cent of the total base-year emissions. Emission reductions from land use, land-use change and forestry (LULUCF) account for only 1 per cent of the volume of CO₂ traded so far. Agriculture benefits from methane capture projects, amounting to 3 per cent of the \$30 billion total carbon trade (FAO, 2008).¹⁶

The "voluntary" carbon offset market is very small compared with the regulated market, but it is more accessible to agricultural projects. The market was worth \$90 million in 2006, of which carbon sequestration from agriculture accounted for \$34 million. The voluntary market for agriculture-based carbon credits is thus worth around 0.1 per cent of the value of the total world carbon market. While there is potential for the voluntary market to grow, the market risks being undermined by concerns over the validity of the offsets, such as lack of additionality (discussed below) and its performance in curbing emissions growth.

International and national agencies support carbon sequestration through specialized funds like the World Bank's Biocarbon Fund and the National Carbon Fund of Italy and the Netherlands. A leading voluntary carbon offset market, the Chicago Climate Exchange (CCX), reports that 40 per cent of its projects fund agricultural schemes under the category Agricultural Methane Offset and Soil Carbon Offset (CCX, 2007). The CCX funds carbon-offset projects for grass tillage and conservation no-till agriculture in the United States. These are farming systems in which the farmer plants crops and controls weeds without turning the

¹⁶ For information on registered projects and approved methodologies in agriculture, see: <http://cdm.unfccc.int/Statistics/index.html>.

soil, thus reducing GHG emissions from the soil and tractor use. The United States also encourages the use of soil carbon sequestration on a modest scale through its agricultural policy and research (Young et al., 2007).

The demand for organically produced food further encourages carbon sequestration and other environmental goods and services from agriculture. In 2007, the global market for organic products was worth \$46 billion, having tripled in value over eight years (Sahota, 2009). Whilst the majority of consumers buy organic products for their perceived health benefits, environmental protection is also cited as a reason.

2. Effectiveness and efficiency

a) Farmers' opportunity costs

The ability of PES schemes to deliver environmental goods and services from agriculture depends to a large degree on the decision-making of farmers. Farmers' management of their natural resources is driven by the market returns for these activities and the broader agricultural policy environment (FAO, 2007). In most property rights regimes, farmers do not have sufficient incentive to adopt environmentally friendly farm practices because these would reduce their net benefits. Depending on the degree to which the polluter-pays principle applies, payments would be needed to compensate farmers for the costs (i.e. forgone income) of the new practices. Other barriers to the adoption of environmentally friendly practices include limited access to information, appropriate technologies and finance, as well as insecure property rights and legal constraints. These constraints are often compounded by poorly functioning markets and infrastructure, risk and difficulties in the collective management of commonly held resources like pasturelands (FAO, 2007).

b) Farmers' transaction costs

Farmers face transaction costs in PES schemes in terms of time and effort spent (and sometimes financial costs) in finding and processing information about those schemes. Transaction costs are higher as a proportion of total costs for small farm enterprises and smallholders than for larger ones. Such costs will thus be considerably higher in developing countries where farm size is much smaller and levels of human capital, farmers' organization and access to markets are much weaker. Luttrell, Schreckenberg and Peskett (2006) identify transaction costs as a major obstacle to the participation of the rural poor in forest-based carbon markets. Specifically, regulated carbon markets (i.e. the CDM) are unfavourable to participation by small farmers for several reasons (FAO, 2007):

- The CDM excludes the two forms of carbon storage that farmers can deliver easily: reduced emissions from deforestation in developing countries (REDD) and soil carbon sequestration. The process of certifying projects to be eligible under the CDM is complex and costly, as is the process of delivering credits to the market.
- The CDM allows simplified procedures for establishing small projects, but sets a cap on the size of these projects. These are too small to make the projects financially viable at the current low level of carbon prices.

The small voluntary carbon market is more accessible to agriculture and does not face either the restrictions on the size of projects or carbon sequestration through agriculture. However, Pannell (2008) questions the financial benefits to farmers of carbon sequestration services on the following grounds:

- Soil sequestration is a one-off process: once farmers change their management to increase soil carbon, it increases up to a new equilibrium level and then stops. After that, there are no net additions of carbon to the soil each year, meaning that farmers would receive only a one-off payment;
- It is difficult to measure the amount of carbon stored in soils. To do so in a convincing way would involve regular and ongoing costs, which would eat away at the modest one-off benefits; and

- It is difficult to increase the amount of carbon stored in most cropped soils, for example in Australia, even with zero till and when large amounts of stubble are retained (Chan, Heenan and So, 2003).

c) Administration costs

Publically funded schemes operate with limited budgets, and therefore have to demonstrate cost effectiveness. A key element of this is ensuring a minimal level of service provision while minimizing the level of administration costs (FAO, 2007). Such costs (or demand-side transaction costs) are potentially high in PES schemes. A survey of 37 case studies of EU agri-environmental schemes revealed administration costs as a proportion of total payments to landholders varied from 6 to 87 per cent (Garnaut, 2008).

Administration costs for sequestration of carbon in agricultural land typically include the following: mapping out the land, estimating its carbon sequestration potential, the costs of sequestration for different farm types, drawing up negotiating contracts and monitoring schemes to ensure agreed environmental actions are taken by farmers. The level of administration costs will depend on the following three factors:

- i) Measurement of the carbon sequestration potential of the land. Measurement costs are higher because of the diverse emissions profiles of individual farmers, and sampling is expensive. Moreover, estimation of emissions and sequestration is difficult because of seasonal, annual and spatial variations. FAO (2008) outlines in more detail the challenges to measuring soil carbon stocks at field scales and larger. Some of the main challenges are that soil carbon contents are often highly variable within an individual field, and multiple factors (e.g. soil type, climate and previous land use) influence soil responses at a specific location.
- ii) Information hidden by the farmer (adverse selection). Farmers can hide information about their costs of compliance with schemes (adverse selection) when negotiating contracts. They have better information than the regulator about the opportunity costs of supplying environmental services and can thus secure higher payments by claiming their costs are higher than they actually are. In other words, farmers may attempt to extract informational rents from the regulator in the form of a higher than necessary payment to induce them to participate in the PES programme (Ferraro, 2005).¹⁷
- iii) Action hidden by the farmer (moral hazard). In contrast to hidden information, hidden action (moral hazard) arises after a contract has been negotiated. Farmers may find monitoring contract compliance costly and thus be unwilling to verify compliance with certainty. Therefore they may avoid fulfilling their contractual responsibilities. This is another instance where the farmers attempt to extract informational rents from the regulator. In this case, the rents arise from payments for actions never taken (Ferraro, 2005).

Reducing information asymmetry by the regulator involves costs, as a higher level of monitoring is needed to uncover hidden action (moral hazard). Uncovering hidden information, for example about the cost of storing carbon requires measuring individual soil profiles and marginal storage costs. Both sets of action require expenditures.

Transaction costs will increase under conditions where property rights are uncertain (e.g. over contract enforcement and land tenure), the number of contracting parties are higher and the concept of PES is unknown. These are common conditions in developing countries, where the potential for carbon sequestration is the highest. Transaction costs can be reduced by simplifying scheme design and contracting larger farmers. There is thus a trade-off between administration (transaction) costs and scheme effectiveness.

¹⁷ For further background information on issues relating to the design of contracts for delivery of environmental services in agriculture, see Latacz-Lohmann and Schilizzi, 2006.

d) Lack of permanence

Environmental benefits in agriculture take a long time to accrue (e.g., building biodiversity values). However, when contracts expire, farmers are under no obligation to continue maintaining the newly formed environmental assets (e.g. soil structure that has a greater capacity to hold carbon). Farmers may then have new incentives (for instance from high commodity prices) to return to more intensive forms of agriculture at the expense of the environmental benefits created. This could apply equally to carbon sequestration contracts, whereby farmers revert to carbon depleting farm practices such as intensified tilling. The degree to which farmers are subsequently rewarded for keeping carbon stored in the soil will depend on the prevailing property rights regimes. If these favour farmers, regulators may be inclined to offer payments to stop farmers tilling land intensively so as to avoid releasing carbon.

e) Lack of additionality

Additionality means that people should be paid for doing things that they were not going to do. This is important if budgets, and therefore resources, are limited. Lack of additionality will reduce the benefits of a programme (Pannell, 2009). Forest-based carbon sequestration schemes have been criticized for not offering additionality. The largest agri-based carbon sequestration market, the CCX, has also been criticized for the lack of additionality in its no-till agricultural projects. There have been several cases where farmers have received carbon offset revenues for practising no-till agriculture despite the fact that they had been practising no-till for many years already (Kollmuss, Zink and Polycarb, 2008).

Whilst conceptually simple, it is difficult to apply the concept of additionality in practice. It is not easy to tell what farmers would have done without the payment, considering that people's behaviour and business management is always in a degree of flux. One strategy is to use an auction or tender-based process whereby participants in a bid reveal what they are willing to do for a certain price, and the regulator can choose those bids that offer best value for money (Pannell, 2009). This system has been applied in developed countries, but is unproven in the weaker regulatory environments of developing countries.

f) Limited practice of organic agriculture

Organic agriculture generates environmental benefits such as carbon sequestration (Niggli et al., 2008a; 2009), but its growth is constrained by unfavourable government policies and limited willingness on the part of consumers to pay higher food prices. Furthermore, the lack of a price for the environmental benefits of sustainable agriculture is a major constraint. There are also implicit subsidies for conventional agriculture in terms of water pollution clean-up costs, particularly in developing countries. Furthermore, the economic costs of biodiversity loss and human health problems from agrochemical use are not reflected in the costs of conventional agricultural production.

Currently 0.8 per cent of the world's agricultural land is under certified organic production (Willer, Rohwedder and Wynen, 2009). The scope for growth in organic production depends not only on increasing consumer demand, but also on government agricultural policies that support the sector's development, for example, through R&D in organic agriculture (Twarog, 2006).

The constraints on carbon sequestration through PES schemes are summarized in table 5.

Table 5. Constraints on sequestration of carbon through PES schemes

Type of constraint	Cost impact	Result	Examples of constraints
Competing market incentive	Farmer	Low participation by farmers	High commodity prices /low carbon prices make environmental practices

			unprofitable
Size limits to scheme	Farmer	Reduced participation by small farmers	Limit to size of simplified CDM schemes
Time and effort collecting and processing scheme information	Farmer	Reduced participation by small farmers	Rural poor highly constrained in forest-based carbon trade
Lack of knowledge about environmental practices	Farmer	Reduced participation by farmers	Lack of knowledge about organic agriculture techniques
Lack of information on land's carbon storage potential	Regulator	High cost of scheme design. Incentive to reduce scheme targeting.	Multiple, for example for Australia, Garnaut Review, 2008; and for developing countries, FAO, 2007.
Hidden action (moral hazard)	Regulator	Non-compliance with scheme due to imperfect monitoring	EU agri-environmental schemes, United States conservation payment schemes
Hidden information (adverse selection)	Regulator	Overcompensation of farmers	EU agri-environmental schemes, United States conservation payment schemes
Lack of permanence	Regulator	Loss of carbon sequestration after scheme	EU agri-environmental schemes. Farmers might feasibly resort to carbon depleting practices at the end of carbon sequestration contracts.
Lack of additionality	Regulator	Financial reward for farmer to do what he/she already intended to do.	CCX contracting no-till cultivation where the farmer was already practicing no-till methods.

3. Equity

PES schemes run the risk of favouring larger farmers who face proportionately lower transaction costs for participation. The transaction costs for farmers can be reduced by simplifying the design of schemes. However, the trade-off is that schemes will have to be less targeted and so risk delivering weaker environmental benefits.

If farmers are offered contracts to reduce methane emissions, they may reallocate their resources away from emission-intensive ruminant livestock rearing to forestry, for example. Cattle and sheep producers are likely to be the first to switch to farming carbon. If this occurs only in Annex 1 countries, beef producers such as those in Argentina and Brazil will benefit from rising prices of their exports.

F. Carbon labelling

1. Background

In 2007, carbon labelling came to prominence in the retail sector with a raft of new labelling schemes that conveyed information about the amount of carbon emitted in the production and processing of products (for reviews of the different schemes, see Bolwig and Gibbon, 2009; Brenton, Edwards-Jones and Jensen, 2008; and the Øresund Food Network, 2008).

There is no universally accepted methodology for measuring the carbon footprint of a product. In principle, it should be based on the measurement of emissions during a product's life – from the production of inputs and their use, to their final consumption and disposal. This process is known as Life Cycle Analysis (LCA).

Carbon labelling has been driven mainly by food retail companies so far, though organic labelling and standard setters are also driving carbon initiatives. Governments provide incentives for the private sector to develop carbon labelling through their legislation and target setting. The reasons why retailers, and to some extent organic standard setters promote carbon labelling are: to demonstrate their corporate commitment to reducing sector GHG emissions (i.e. corporate social responsibility (CSR) commitment), to differentiate their products according to “green” consumer preferences (i.e. marketing purposes), and to identify carbon “hotspots” within the supply chain and take measures to reduce them (i.e. cost-saving purposes).

In the agri-food sector, Walmart, Tesco and Casino have been the most prominent retailers in developing carbon labels across a range of mainly food products. Tesco, for example, launched a trial of 20 products in 2007. In 2007, the United Kingdom's Carbon Trust tested its standard with 20 companies, mainly in the agri-food sector, including Tesco. In France, Casino launched a label that provides information on the amount of CO₂ emitted in three stages of the supply chain: packaging, waste and transport. In the apparel sector, Patagonia and Timberland are both displaying carbon information on a limited range of their products. However, not all in the retail sector are involved in carbon labelling. For example, in 2008, Unilever, ASDA (the United Kingdom retailer and subsidiary of Walmart) and Carrefour were seeking to reduce their supply chain emissions through initiatives other than carbon labelling. These included, for example, installing energy-efficient technologies, switching to renewable energy sources and offsetting travel emissions through support for renewable energy initiatives in developing countries (Øresund Food Network, 2008).

Several organizations involved in organic certification and standard setting are developing standards that incorporate carbon accounting. For example, the Swiss organic labelling organization, Bio Suisse, does not give certification to air-freighted products (see box 1). In 2009, the main Swedish organic certifier, KRAV, was considering climate provisions in its new draft standards (Gibbon, 2009).

In Australia, the Carbon Reduction Institute (CRI) certifies organizations, including retailers, based on their GHG emissions. It markets a “NoCO₂” certificate, which signifies that a business is carbon-neutral and has accounted for, reduced and offset all GHG emissions from its operations as well as the GHG emissions embodied in the products it sells and uses. The CRI awards certificates of carbon credits to energy efficiency, renewable energy and tree planting projects. The agri-food sector in Australia has shown a strong interest in this certification scheme (Øresund Food Network, 2008).

At EU and member State level, government legislative requirements and target setting are driving the development of carbon labelling. The EU has a target to reduce GHG emissions by 20 per cent by 2020. The European Commission has proposed new regulations to specify mandatory requirements for measuring the carbon footprint of biofuels. The EU ETS may include agricultural and small food processing companies in the future, thus creating an incentive for them to cut their GHG emissions (Øresund Food Network, 2008). The International Organization for Standardization (ISO, 2006) has developed its own meta standard, which specifies principles and requirements that organizations can use for quantification and reporting of GHG emissions.

At the government level, France has set sustainability objectives for its retail sector, including proposed mandatory carbon accounting. The Government of the United Kingdom has set up the Carbon Trust, which has developed a pilot methodology to measure the carbon footprint of products as well as a label to display information about the products' carbon footprint. The Carbon Trust is working with public agencies to produce a standardized methodology for

carbon accounting (known as the PAS 2050), which may serve as the basis for a future standard in that country (Brenton, Edwards-Jones and Jensen, 2008). Australia has established a National Carbon Accounting System (NCAS) that accounts for GHG emissions from land (Department of Climate Change, 2009).

Box 1: Swiss organic markets and import restrictions: the case of Bio Suisse

The Swiss organic labelling organization Bio Suisse has incorporated food miles measures into its standards. Some of the criteria for awarding its label include:

- Products imported into Switzerland by land or sea (but not by air transport);
- Priority to organic imports from nearby countries; and
- Products for which all the processing is carried out abroad.

Fresh products (fresh fruit, vegetables, herbs), fruit juices and frozen products from overseas (except the Mediterranean) cannot be labelled with the Bio Suisse organic label (BioBud). Products which are “detrimental” to the image of the Bio Suisse label may be refused a licence contract. The following criteria may apply: “Ecology, transport distances, packaging, consumer expectations”. Examples of products which have been refused contracts in recent years due to this restriction are: wine from overseas, tinned tomatoes from overseas, caviar and instant ice tea.

The preference for Swiss products appears to be based on meeting the wishes of consumers. Jacqueline Forster-Zigerly of Bio Suisse said in 2008: “In a time of globalisation, it becomes more clear how important it to have a strong national or regional profile. We notice that the consumers are becoming more interested in locally-produced products, sometimes even more interested than in the organic products”

(The Organic Standard, 87: 3).

2. Effectiveness and efficiency

Carbon labelling potentially provides the consumer with information about the levels of GHG emissions associated with the life cycle of a product. According to retailers, this information will drive demand for low-carbon technologies and help reduce the sector’s GHG emissions. The use of carbon accounting methods by companies can also help them identify climate “hotspots” in their supply and take mitigating actions.

All attempts to regulate GHG emissions need to address issues of measurement. However, there are additional problems with carbon labelling, discussed below.

a) Measurement methodology

Brenton, Edwards-Jones and Jensen (2008) identify four key elements for measuring GHG emissions that can have a critical impact on determining the quality and reliability of measurement:

- *The use of primary versus secondary (standardized) data:* it is preferable to use primary data (i.e. process-specific data collection from the supply chain) as opposed to secondary data (i.e. non-process-specific data obtained from other sources, rather than direct measurement of the supply chain being investigated). Primary data collection is very expensive, and is rarely done in developing countries. Many companies therefore prefer to use a standardized approach relying on secondary data. However, this will not capture low-carbon technologies being used in developing countries or the varying levels of emissions from different farms producing the same crops. Without this capacity to measure farm level efficiencies, the carbon label is rendered ineffective as a tool to induce low-carbon technologies. In addition, secondary data collection cannot capture annual variations in GHG emissions and thus the label would convey an inaccurate measurement.

- *Emission factors*: the amount of carbon emitted during a particular part of the manufacturing process and/or use of products are called emission factors. However, these are location-specific. For example, a country that generates a large proportion of its electricity from nuclear power or hydro power will have lower emission factors than a country that relies more on coal-powered electricity. The carbon foot-printing methodology cannot capture these differences.
- *System boundaries*: these define the extent of processes included in the measurement. System boundaries may be defined so that they include only certain elements of the supply chain. For example, in agriculture, the boundary may extend to the use of heat and electricity in a farm building and machinery but not the energy used in their construction. Similarly, farm workers in developing countries tend to walk or cycle to work, while those in developed countries use more private transport. The definition of the system boundaries in methodologies can therefore favour capital-intensive production techniques over labour-intensive techniques, and thus disadvantage developing countries.
- *Land-use changes*: when food demand brings about changes in land use (for example organic farm conversion or ploughing of pasture for arable production) there is a change in the carbon composition of the soil. For example, clearing forests for agriculture is the main cause of deforestation in developing countries. However, it is difficult to measure changes in GHG emissions. Furthermore the labelling scheme has to determine over how many years the one-off increase or decrease in emissions should be spread.

Since measurement is also very expensive, it is undertaken only by a limited number of retailers. Moreover, consumers are likely to be confused when different methodologies are used by different retailers.

Øresund Food Network (2008) has identified other major limitations to carbon labelling:

- *Exclusion of other environmental impacts*: by measuring only carbon emissions, the process ignores other impacts, such as the use of pesticides, biodiversity impacts, water usage and other GHGs (particularly methane and nitrous oxide). A similar criticism has been levelled against food miles.
- *Consumer confusion*: another label may well confuse consumers. It is not clear that consumers will understand the meaning, for example of “75g CO₂” for Walkers crisps. While labels may develop in a way that addresses this problem, for example by providing supplementary information, the consumer will simply have more and more information to process and understand. On the introduction of carbon labels by Tesco in April 2008, the National Consumer Council of the United Kingdom observed that it would be hard for consumers to understand what a gram of carbon was and to make a properly informed green decision on this basis. It noted: “Including this on a consumer facing label at this early stage of development could cause more harm than good” (NCC, 2008). Consumer confidence in labelling is also undermined by the different ways in which labels convey information. Companies currently present carbon labels in three different ways: according to the products’ CO₂ equivalent per kg, use of a number and colour coded system, and a “climate friendly” or “carbon neutral” label without quantified information.
- *Criticism of climate neutrality*: companies are claiming “climate neutrality” for their businesses, products and services. Tree planting or energy efficiency offsetting projects are criticized for being ineffective in reducing emissions or for having negative impacts on local communities and their access to and use of land. Furthermore, there is no industry-wide standard on what constitutes climate neutrality. For example, for air travel, different companies offer to offset GHG emissions based on different GHG emission rates per km and different prices per ton of carbon.
- *Usefulness of a carbon label*: a carbon label does not capture the energy used by the retailer in storing the goods, nor by the consumer in travelling to the supermarket and preparing the food. Yet these parts of the supply chain constitute up to 60 per cent of total GHG emissions. It therefore does not give the complete picture of GHG emissions from “farm to fork”. The label may even have perverse outcomes, as consumers may feel they

are making a contribution to mitigation of climate change by buying low-carbon goods yet travelling to the supermarket and preparing the food in energy-intensive ways.

The interests of developing countries in the development of carbon standards will depend on the extent of their participation in the standard setting process. According to Brenton, Edwards-Jones and Jensen (2008), most carbon labelling standards are currently developed in a way that is not inclusive in this respect.

Life cycle analysis (LCA) studies illustrate that distance is not necessarily an important indicator of the environmental impact of a food product (see section G.2). However several climate-related standards have been developed by organic standard setting organizations in which the developers of the standard have concentrated exclusively on transport. In one case, no scientific work was referred to at all, while in a second case scientific findings and methods were referred to only selectively. In the third case, where LCA analysis was adopted to help measure GHG emissions, provisional results were combined with maximum limit levels that were justified on non-scientific grounds (Gibbon, 2009).

These standards have thus been heavily criticized and the transport components dropped, except in the case of Bio Suisse (box 1). In the end, the demands of the retailers to maximize supply and demand leave proponents of climate standards exposed when attacked from other sources (e.g. producer groups and development organizations) (Gibbon, 2009).

3. Equity

The impact of carbon labels on developing-country exports depends on several factors, including:

- The compliance costs exporters face compared to the higher prices they might receive;
- The relative carbon intensity of production and transport compared with European products; and
- The likelihood that technologies can improve their “carbon competitiveness”, for example by reducing emissions in refrigeration and shipping.

Data in table 2 suggest that developing countries tend to have lower carbon intensity in agricultural production, reflecting the greater use of labour as opposed to fuel-consuming equipment, fertilizers and pesticides. Comparisons between countries are difficult because of differences in the composition of exports, but the generalization appears to hold for lower levels of aggregation (i.e. what holds for agriculture as a whole also holds for crops, livestock and so on). However, the premium and costs of compliance associated with the carbon label will determine its profitability.

Edwards-Jones et al. (2009) highlight the different levels of vulnerability of countries to embedded carbon import requirements. Countries “highly vulnerable” to the introduction of carbon labels to the supply chain include those that rely on:

- Crops that are air-freighted (and possibly substitutable (e.g. green beans from Kenya));
- Crops with a favourable carbon footprint for only a few months in the year (e.g. apples imported into Europe from Argentina or New Zealand); and
- Crops with a higher carbon footprint than EU production and which are vulnerable to technological advances in the EU agricultural sector (e.g. onions from New Zealand).

Traditional tropical commodity crops such as coffee, cocoa, tea and bananas are not vulnerable because although they are produced far from the market their local substitution is not possible.

Carbon labelling, and the food miles initiatives discussed in the next section have the likely outcome of setting new requirements that would entail increased costs for exporting countries. There is limited evidence to date of how consumer behaviour and retailer demands will affect suppliers in developing countries. The impact will depend on the following:

- Degree of product substitution;
- Consumer reaction to embedded carbon approaches;

- Retailers' demands in the supply chain; and
- Integration of embedded carbon approaches in standard setting.

Each of these is discussed below.

a) Degree of product substitution

The degree to which an imported product can be substituted by a domestic product is important in determining vulnerability from mitigation measures like carbon labelling. Food exports of developing countries are still primarily commodity crops. Some of these crops such as tea, coffee and bananas cannot be readily substituted by European or United States production, whereas other commodities like vegetable oils, sugar, rice, tobacco and cotton are all substitutable. Higher value non-traditional exports, which have grown rapidly in recent years, are vulnerable to substitution. For example, Kenyan beans can feasibly be substituted in the northern hemisphere's summer period.

Edwards-Jones et al. (2009), however, point out that it is unclear when consumers are actually presented with a genuine choice between substitutable products. Fresh produce supply chains to major retailers in the United Kingdom, for example, are generally very well differentiated by season and products. Thus, consumers are unlikely to be presented with the choice of purchasing new potatoes from Israel and the United Kingdom on the same day. Therefore the degree of partial or total substitution across product lines tends to vary.

b) Consumer reaction

It is uncertain how consumers will respond to carbon labelling. A large proportion of "ethical" consumers are aware of carbon labels (Bourke, 2008¹⁸). However, it is unclear how consumers will prioritize these over other more established environmental and social attributes (no pesticides, food safety, child labour issues, fair trade and biodiversity). Furthermore, whilst some environmental food labels command a premium price (e.g. organic), it remains to be seen to what extent consumers will pay a premium for low-carbon products.

c) Retailer demands

Even if consumers do not show a strong preference for low-carbon products, retailers may require suppliers to provide information relating to carbon accounting. This could include such aspects as energy costs, types of technology employed, transport distances and carbon action plans in production and processing. This represents an additional barrier confronting exporters.

d) Integration of embedded carbon approaches in organic standard setting and labels

Carbon labelling is a voluntary initiative. Retailers have promoted local products, but so far have not actively excluded imported products. However, in the organic niche market, more serious obstacles have arisen. One of the most visible examples of integration of embedded carbon into food standards to date has been the decision of the leading Swiss organic label Bio Suisse to refuse to provide its organic label for air-freighted products. The Soil Association also considered such a move, but after broad consultations dropped the idea because of the apparently large detrimental development impact this would have.

G. Food miles

1. Background

Food miles refer to the distance travelled by food from the farm gate to the consumer. In other words, they count the miles between where the food is produced and where it is consumed. Since the transport of food consumes energy and is therefore responsible for GHG emissions,

¹⁸ A survey of organic consumers in Ireland showed that 60 per cent of respondents were aware of carbon labels.

it follows that the further a product travels to market from the production site, the greater its environmental damage and contribution to global warming. To reduce this environmental impact, environmental groups encourage consumers to buy locally. Major retailers and farm lobbies have joined this campaign, which also promotes local economies and regional and local food sourcing. In Europe, air-freighted products receive particular attention, especially from organic standard setters.

Labelling is the most common way retailers convey messages, such as about local sourcing, to consumers. With food miles, a common way of indicating that a product has been imported by air is to show the sign of a plane on the label.

2. Effectiveness and efficiency

The food miles approach is criticized as an oversimplified way to address the environmental problem of GHG emissions (see, for example, Edwards-Jones, 2006; McKie, 2007; ITC/UNCTAD/UNEP, 2007; Wynen and Vanzetti, 2008). The main points of criticism are:

- Its lack of a life cycle approach;
- Omission of sustainability impacts; and
- Omission of political economy variables.

a) Lack of a life cycle approach

The food miles focus on distance is a crude indicator of environmental damage as it ignores the difference in GHG emissions between different forms of transport and energy costs in other stages of the supply chain. It also ignores non-carbon GHGs. As illustrated earlier in figure 2, the use of energy in production systems and cold storage as well as by consumers in shopping and food preparation is also significant. Efficiencies in these areas can offset emissions from transport over great distances (as illustrated in figures 3 and 4).

Life cycle analyses (LCAs) illustrate where energy costs fall in each stage of the supply chain from “farm to fork”. Such analyses have demonstrated that areas other than transport can be an important contributor to the carbon footprint of food products. LCAs have provided a number of insights, discussed below.

b) Production systems can compensate for energy costs from transport and storage

Certain production systems and locations are more energy-intensive than others. Tomatoes grown in greenhouses in Sweden, for example, were found to be 10 times more energy-intensive than those grown in open fields (Carlsson-Kanyama, Ekstrom and Shanahan, 2002).

Saunders, Barber and Taylor (2006) compared energy use and emission levels in the production and transport (from a New Zealand to a United Kingdom port) of several commodities (see figure 3 for dairy products and lamb, and Figure 4 for apples and onions, which include storage). They concluded that with 3 of the 4 products, emissions were lower when produced in New Zealand and transported by sea to the United Kingdom than when produced in the United Kingdom. The length of time that food is stored prior to retail can add substantially to GHG emissions. Saunders Barber and Taylor (2006) showed that the cold storage used to allow consumption of out-of-season apples can account for over 40 per cent of a product’s energy inputs. Sim et al. (2007) found that the impact on global warming of locally grown United Kingdom produce placed in storage for 10 months was twice as high as that of South American apples sea-freighted to the United Kingdom.

Figure 3. Comparative CO2 emissions per ton of dairy and lamb produced in New Zealand and the United Kingdom

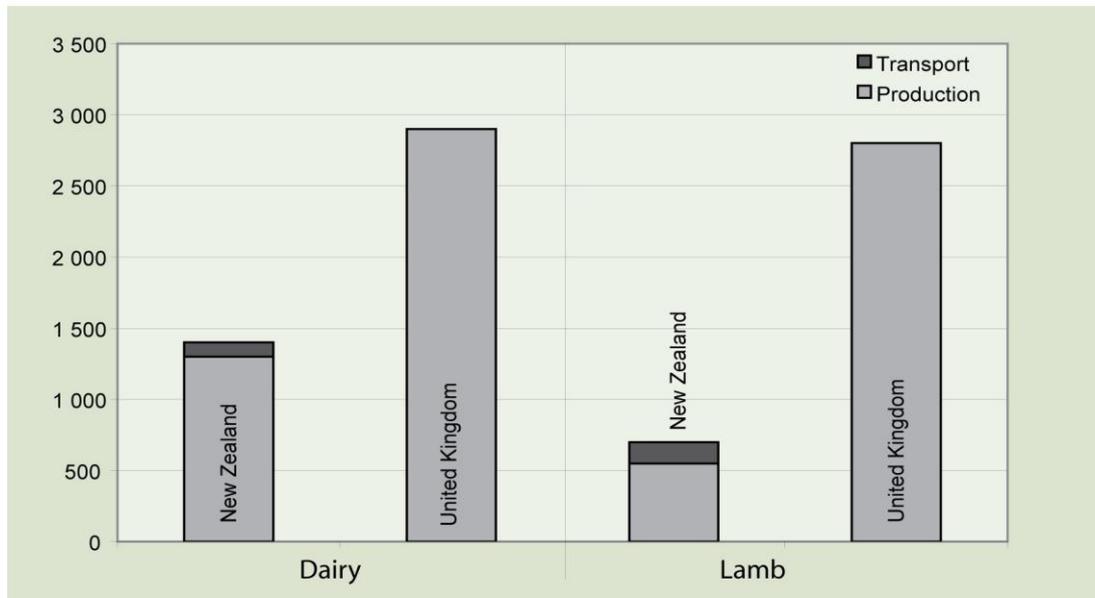
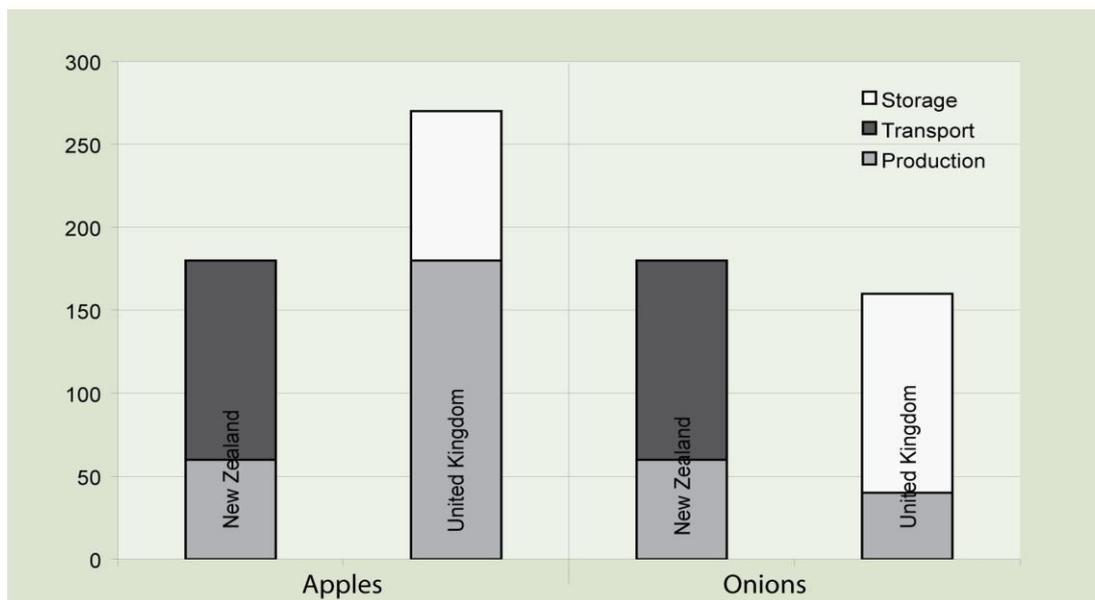


Figure 4. Comparative CO2 emissions per ton of apples and onions produced in New Zealand and the United Kingdom



Each of these case studies is based on sea-freighted transport. Air freight is very energy-intensive and normally does not compensate for lower energy costs associated with production in warmer climates like Kenya. Several studies have shown that fruit and vegetables grown in Kenya and air freighted to Europe involve substantially higher GHG emissions – around 10 times greater (Jones, 2006; van Hauwermeiren et al., 2007). Williams, Audsley and Sandars (2006) found that the carbon footprint of flowers grown in open fields with geothermal power in Kenya and air freighted to Europe was lower than that of flowers grown in greenhouses (and heated by fossil fuels) in the Netherlands.

c) Transport mode and efficiency

The climate impact of emissions from transport depends on the mode of transport and its efficiency: air freight has high emissions, while sea freight emissions are lowest followed by rail and road.¹⁹ Road haulage accounts for the most noise and air pollution costs, while shopping for food by car accounts for the most accidents and congestion impacts (AEA Technology, 2006). There is a trade-off between transport distance, vehicle size and transport efficiency. The food distribution system of large vehicles when travelling large distances between regional distribution centres involves efficient loading of vehicles and thus reduces the impacts per ton of food. Local markets have shorter distances but less efficient loading through greater use of smaller vehicles (AEA Technology, 2005).

d) Consumer travel and food preparation

Consumer travel to the supermarket, storage and food preparation account for 13 per cent of total food chain energy costs. Although the choice of transport that consumers use to get to and from the supermarket does not depend on whether the product is imported or not, it can make a large difference in terms of energy and CO₂ emissions associated with food. Van Hauwermeiren et al. (2007) found that a 5 km trip to purchase 25 kg of food (when combined with other activities), will incur an impact of 100g CO₂/kg of food. This compares with no emissions from shopping using a bicycle or on foot. The authors examined the relative impact of specific (i.e. solely to purchase food) shopping trips greater than 10 km. A consumer driving more than 10 km to purchase one kg of fresh produce will generate more GHG emissions than air freighting 1 kg of produce from Kenya.

Food preparation methods also vary in their energy intensiveness, which is not necessarily known by consumers. Baking potatoes, for example, requires over five times more energy than boiling them (Carlsson-Kanyama, Ekstrom and Shanahan, 2002). Similarly, preparing dried chickpeas (boiling over several hours) is considerably less efficient than buying ready-cooked tinned chickpeas. This is because cooking them at home on a stove is much less efficient than the large-scale industrial kitchens used when cooking for canning. The level of carbon intensity also depends on whether the consumer is using renewable energy, nuclear or coal-fired sources, all of which have very different carbon emission levels (McKie, 2007).

e) Omission of other sustainability impacts

If imports were to be excluded on the basis of international transport alone, this would omit consideration of the environmental benefits from traditional or organic farming systems associated with imports. For example, the exclusion of air-freighted organic products from certification in European countries may result in producers reverting to farm production using agrochemicals (Gibbon and Bolwig, 2007). In developing countries, where enforcement of environmental regulations is weak, there are well-documented cases of water pollution from agrochemicals and hazards for farm workers who handle pesticides. A return to chemical-based agriculture would lead to the loss of environmental benefits associated with organic agriculture, such as its effects on biodiversity and its carbon sequestration functions. Improved incomes from the premium prices for organically produced foods would also be at risk from the loss of organic export markets (Bolwig, 2007; Twarog, 2006; Bolwig and Gibbon, 2007).

f) Omission of political economy variables

Arguments that support the consideration of food miles cannot capture important policy variables such as subsidies for farm fuel use in some countries (e.g. Australia and the United

¹⁹ Although there are difficulties in measuring these costs, and hence data should be used with care, an OECD report suggests costs in Germany of around €25.8 per ton per 1,000 kilometres for road transport, €3.7 for rail and €1.8 for waterways (Quinet, 1999: 28).

Kingdom). These subsidies are disguised by effectively imposing a much lower duty on farmers than on non-agricultural users. Insofar as taxes on fuel cover activities on the road, such as building of the roads and costs associated with accidents, the imposition of lower taxes on fuel used in farm machinery but not that used off the farm has some merit. However, when taxes are raised to curb polluting emissions, there is less reason to exempt one group and not another. The ITC (2008) has argued that it is discriminatory to exclude imported products on the basis of transport – and fuel use – yet accept local products farmed with energy subsidies, thereby presumably stimulating the use of fuel.

3. Equity

The impacts of food miles campaigns and labelling schemes are likely to be similar to those of carbon labelling. These are summarized in section F.3, and therefore not repeated here. An additional factor is that developing countries tend to be more distant from the major markets, which would result in their being effectively discriminated against in any food miles scheme. This approach therefore has less merit than carbon labelling, which is a more sophisticated approach to measuring embodied carbon.

H. Summary and discussion

1. Addressing population and demand for meat

The agricultural sector, including products that are traded internationally, accounts for a high share of total GHG emissions. These emissions are increasing, driven both by a growing population and growing demand for ruminant meat. Upstream emissions (processing, transport, retail and consumption) are also growing.

This paper has identified market-based mechanisms as the most effective, efficient and fair way to reduce emissions from traded agricultural products. However, even market instruments are limited in their effectiveness because of the difficulty of implementing monitoring, reporting and verifying schemes in agriculture. Nevertheless, it is important that market-based mechanisms prevail. A regulatory or voluntary approach would be unnecessarily expensive or ineffective, and would render the task of achieving the necessary GHG emission reductions far more difficult.

Pricing externalities effectively in transport, processing, retail and consumption is feasible, but it has only limited political support. The prospects for reducing emissions in the agricultural sector and its trade are therefore extremely dim, given the following key factors:

- The technical and political challenges in pricing externalities across the sector;
- The growing population; and
- The growing demand for ruminant meat.

Table 5 summarizes the effectiveness, efficiency and equity of market-based instruments and measures. A number of further key points are summarized below.

2. Pricing negative externalities: the most effective and efficient and fair policy

The benefits of adopting global mitigation policies are obvious. The most effective, efficient and fair policy for climate change mitigation across the agri-food supply chain is through carbon pricing. Pricing carbon internalizes the environmental cost of production and removes an implicit subsidy for carbon use.

Ending fossil fuel subsidies would also remove an explicit subsidy for carbon use, and represents “low hanging fruit” in terms of climate change mitigation.

Pricing carbon upstream would automatically internalize the costs of damage from GHG emissions across the agri-food supply chain, which would provide an incentive for emissions reducing behaviour and for the development of low-carbon technologies throughout the supply chain.

The economic impact of a carbon tax on developing countries' agriculture would be slight because of the low carbon intensity of the sector.

Carbon pricing is limited in its effectiveness if it is not applied globally. Without global pricing, there is the risk of "leakage" (i.e. relocation of industry and an undue impact on competitiveness, particularly in carbon-intensive sectors). Industry is likely to respond to these competitive pressures by either seeking border adjustments or lobbying against stringent mitigation measures. However, global and upstream carbon pricing is currently politically unfeasible. Global fossil fuel producers seem unlikely to accept such a policy. Carbon pricing also runs counter to the concept of "common but differentiated responsibility" as it restricts carbon-intensive fast growth paths.

Carbon pricing is also proving difficult to introduce in 1 developed country due to opposition from the public and industry lobbies. Recent experiences in Australia, the EU and the United States point to difficulties in implementing a cap-and-trade scheme in the face of opposition from those industries adversely effected.

3. The benefits of mitigation policies: need for further exploration

Policymakers and climate negotiators have to weigh the short-term costs to economic development of carbon reduction commitments against the longer term economic costs that unconstrained growth will cause through climate change. Stern (2007) calculates that "the benefits of strong, early action considerably outweigh the costs...the earlier effective action is taken, the less costly it will be." Further research is needed to help countries compute and communicate this trade-off between sacrificing some growth now for avoiding larger economic costs through inaction on mitigation later.

Making a commitment to carbon reductions has economic benefits as well as costs, for example in the "green economy". Research and development in sustainable agriculture and climate mitigation technologies, including in developing countries, would benefit greatly from countries signing up to carbon reduction commitments. Further knowledge and dissemination about these benefits is needed.

4. Difficulties in mitigating emissions in the agricultural sector

The unique emissions profile of agriculture and the large number of emitters (i.e. farmers) make it difficult to design emissions reduction strategies for the agricultural sector. Most of the GHG emissions from agriculture (90 per cent) consist of methane and nitrous oxide. These emissions cannot be easily incorporated into a GHG emissions reduction scheme. Establishing an MRV system is technically difficult and costly. Furthermore, unlike industry and services, emitters in agriculture (individual farmers) are small, numerous and diverse. Partly for this reason, current cap-and-trade schemes do not include agriculture. In this regard, an important market incentive for increasing the sustainability of agriculture (i.e. pricing GHG emissions) is missing. Until such MRV issues are resolved, market-based instruments are limited in their ability to reduce methane and nitrous oxide emissions.

5. Carbon dioxide emissions are still a significant part of total agri-food supply emissions

Emissions from agricultural production only make up around a third of total GHG emissions in the agri-food supply chain. The rest are carbon-intensive processes, including input production (fertilizers, pesticides), processing, transport, retail, consumer travel and food preparation. Therefore pricing instruments for reducing carbon use are still very important means for reducing overall supply chain emissions.

Table 6. Summary evaluation of market-based instruments and voluntary measures aimed at mitigating GHG emissions in the agri-food sector

Instrument	Effectiveness	Efficiency	Equity (distributional)	Equity (agricultural export impact)
Carbon tax	High, if applied globally ^a and upstream	High, if globally applied	Potentially regressive, although can be made revenue neutral	Insignificant ^b
Cap-and-trade scheme	High, if globally, upstream and with auction of permits ^c	High, if globally applied.	Potentially regressive, but depends on capacity to compensate losers	Insignificant
Border tax adjustment	Low ^d	Low ^e	Ambiguous, depends on sector	May disadvantage some developing countries but favour others
Payment for environmental services (PES)	Low with high opportunity costs for farmers	Low with high transaction costs	Disadvantageous for small farmers	Minimal
Carbon labelling	Low	Low	Favours larger exporters	Negative impact on countries using air freight or shipping over long distances ^f
Food miles initiatives	Low, perverse effects possible	Low Marketing costs	Favours local producers	Negative impact on countries using air freight or shipping over long distances

Notes:

^a Limited impact on non-carbon GHG emissions, for example methane and nitrous oxide from ruminants.

^b Insignificant impact on developing-country agri-exports due to low carbon intensity of agricultural trade. Tax revenue could fund adjustment to sector losses and to adaptation.

^c Concern over price volatility and MRV constraints in agriculture. Limited impact on non-carbon GHG emissions.

^d More effective for carbon-intensive items.

^e Need to measure embedded carbon in imports.

^f Inaccuracy in the data is especially likely for developing countries. Potentially high compliance costs for exporters.

6. Carbon taxes are preferable to cap and trade

Carbon taxes have some advantages over cap-and-trade schemes in terms of stability of prices, flexibility and revenue potential. Regressive impacts resulting from carbon pricing can be reduced through compensation and by lowering taxes on employment and income. Trading schemes must auction permits to function effectively and to create an income stream to use as compensation. Carbon taxes by definition raise this income.

7. Payment for carbon sequestration is a relatively ineffective and inefficient policy

Payment for environmental services schemes, including offsets for reducing methane emissions and storing carbon, appear to be limited in their effectiveness as a mitigation measure for agriculture. Unless the price of carbon is raised sufficiently high, such schemes are likely to be of limited economic interest to farmers. Designing effective schemes also incurs high transaction costs due mainly to the need to profile heterogeneous land types and farmers and to contract and monitor many different farmers. Lack of demonstrated “additionality” raises concerns about the credibility of the offset market. The use of offsets threatens the functioning of a carbon market, because the link between polluters and the appropriate tax is broken.

8. Carbon labelling schemes and food miles campaigns are costly, ineffective and potentially unfair to developing-country exporters

Carbon accounting or LCA is a useful tool for identifying carbon “hotspots” in the agri-food supply chain. It enables companies to identify the most cost-effective areas for energy saving investments. However, carbon product labelling (which uses carbon accounting) is costly and is therefore unlikely to be widely adopted in a meaningful form. There is no commonly adopted methodology across different retailers, which makes it difficult for consumers to compare and comprehend the different labelling schemes. Their effectiveness in curbing emissions is further undermined by their voluntary nature, which allows free-riding by less “conscientious” consumers. In addition, there remain concerns about the potentially inequitable impact on developing-country exporters.

Food miles initiatives are a blunt and ineffective tool for measuring the environmental impact of food production and trade, and they may have perverse impacts, for example where imported produce is more energy efficient than local products despite the distance travelled. Neither carbon labelling nor food miles initiatives take into account consumer energy use in shopping and food preparation. Moreover, they could have a negative impact on vulnerable exporting countries, like high-value fruit and vegetable exporters in sub-Saharan Africa. There is strong evidence of a lack of a scientific basis in decision-making and insufficient transparency in the climate standard setting process. This should be of concern to exporters, particularly in developing countries.

Notes

¹ In this paper, market-based instruments include carbon taxes and offsets, although, strictly speaking, these are fiscal instruments.

² Carbon dioxide equivalent expresses the amount of global warming by GHGs normalized to the equivalent amount of CO₂ that would have the same global warming potential (GWP). The major examples of such GHGs are methane and nitrous oxide.

³ The net flux of CO₂ between agricultural land and the atmosphere (released from microbial decay and burning of plant litter and organic matter in the soil) is approximately balanced (0.04 Gt of CO₂/yr). However, the emissions from fuel and electricity used in agriculture are included in other sectors (transport and building) (Smith et al., 2007).

⁴ For more information on this, see the commentary by Niggli in this Review.

- ⁵ Several general principles can be applied to help growers select sustainable management practices: (i) selection of species and varieties that are well suited to the site and to conditions on the farm; (ii) diversification of crops (including livestock) and cultural practices to enhance the biological and economic stability of the farm; (iii) management of the soil to enhance and protect soil quality; (iv) efficient and humane use of inputs; and (v) consideration of farmers' goals and lifestyle choices. Examples of some of the key specific strategies of sustainable agriculture are: organic farming, low external input sustainable agriculture (LEISA), integrated pest management, integrated production (IP) and conservation tillage.
- ⁶ Under the 2003 EU CAP reform, farm support shifted from price support to direct payments to farmers. Payments are contingent, or "cross compliant", on farmers respecting environmental requirements set at EU and national levels.
- ⁷ Apart from agriculture, the other non-ETS emission sources include transport, households, services, smaller industrial installations and waste. Agriculture represents up to 40 per cent of emissions by the non-ETS sector (Breen, Donnellan and Hanrahan, 2009).
- ⁸ In this regard, see also the commentary by Ackerman in this Review.
- ⁹ For a description of the GTAP model, see Hertel, 1997.
- ¹⁰ Author's estimates using the GTAP version 7 database (Dimaranan, 2006). The estimates apply to a 2005 base period and assume no technological improvements.
- ¹¹ For more information in this regard, see the commentary by Rae in this Review
- ¹² Garnaut (2008) cites Beauchemin et al. (2008) as claiming a 20–40 per cent reduction in methane emissions through better nutrition, but these changes are not cost-effective.
- ¹³ For a full discussion of BTAs, "leakage" and competitiveness issues, see WTO-UNEP, 2009.
- ¹⁴ For information on registered projects and approved methodologies in agriculture, see: <http://cdm.unfccc.int/Statistics/index.html>.
- ¹⁵ For further background information on issues relating to the design of contracts for delivery of environmental services in agriculture, see Latacz-Lohmann and Schilizzi, 2006.
- ¹⁶ A survey of organic consumers in Ireland showed that 60 per cent of respondents were aware of carbon labels.
- ¹⁷ Although there are difficulties in measuring these costs, and hence data should be used with care, an OECD report suggests costs in Germany of around €25.8 per ton per 1,000 kilometres for road transport, €3.7 for rail and €1.8 for waterways (Quinet, 1999: 28).

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