Price effects of an emissions trading scheme in New Zealand

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Paper prepared for presentation at the 107th EAAE Seminar *"Modelling of Agricultural and Rural Development Policies"*. Sevilla, Spain, January 29th -February 1st, 2008

This research was part of the 'Ecological Footprint Plus' programme, funded by the Foundation for Research Science and Technology, New Zealand (Contract Number: WROX0305).

Abstract

Implementation of a New Zealand Emission Trading Scheme (NZ ETS) will begin in 2008, beginning with forestry, subsequently including energy and industrial emissions, and finally, agricultural GHGs from 2013. Reducing agricultural emissions is a major challenge for New Zealand as they account for over half its total GHG emissions. On the other hand, agriculture is critical to the economy, with its basic and processed products accounting for a third of exports. We use an environmental input-output model to analyse direct and indirect cost impacts of emissions pricing on food and fibre sectors. At NZ $25/t CO_2-eq, costs of energy-related emissions on the food and fibre sectors are very small; however, costs of agricultural emissions post 2013 would substantially impact on sheep, beef and dairy farming. Cost-effective mitigation measures and land use changes should help reduce micro– and macroeconomic impacts, but the latter may also risk 'emissions leakage'.

Key words: emissions trading; input-output price model; agricultural greenhouse gases

1 Introduction

New Zealand Emissions Trading Scheme (NZ ETS)

New Zealand is obliged to reduce its greenhouse gas (GHG) emissions to 1990 levels in the first commitment period (2008–2012) of the Kyoto Protocol. New Zealand a GHG emissions profile very different from other developed nations. The agricultural sector accounts for 48.5% of NZ emissions, not including its use of energy. Of the six GHGs covered by the Kyoto Protocol, CO_2 accounts for 46.5%, CH_4 for 35.2%, N_2O for 17.2%, and the other gases (HFCs, PFCs and SF_6) for 1.1%. Recent government projections are that the most likely net emissions position will be a deficit of 45.5 Mt CO_2-eq. This assumes that 58 Mt of net removals by forests (RMUs) will be applied to offset emissions. In September 2007, the government announced a new set of climate policies, the centrepiece being a New Zealand Emissions Trading Scheme (NZ ETS). This paper considers how the scheme may impact on costs and GHG emissions in the food and fibre sectors, which are central to New Zealand's economy.

In 2001, Treasury suggested introducing a broad-based tax on GHGs (NZ Treasury, 2001). In 2002, a climate policy package was announced including a carbon tax to apply initially to energy, industrial and transport emissions from 2007. Large emitters at competitive risk could enter 'Negotiated Greenhouse Agreements' (NGAs), exempting them from the tax if they reduced emissions to 'world best practice'. While agriculture emissions were not included, farmers would face a small research levy on ruminant animals. What was dubbed the 'fart tax' was strongly opposed, and the government soon backed down on this. There were many other problems though: the forestry sector objecting to the government 'stealing their credits', disagreements around NGAs, and a major revision of forest sink calculations that changed New Zealand's expected net Kyoto credit into a net liability. In December of 2005, following a review (Ministry for the Environment, 2005), the tax was finally scrapped completely.

Unlike the ill-fated carbon tax, the NZ ETS has achieved a high degree of political consensus. There may be several reasons for this. Firstly, the last several years have seen substantial strengthening and broadening of public and political consensus in New Zealand around the reality of climate change and the need to take significant action to reduce emissions. Secondly, the proposal has been developed (and will be developed further) with much more extensive consultation than was the case for the GHG/carbon tax policies The result appears to be a careful balance between short-term pragmatism and longer-term objectives of policy effectiveness, efficiency and equity (Kerr, 2007). Thirdly, the ‘cap and trade’ system may simply have more popular appeal than what was seen by some as being ‘yet another tax’.

The NZ ETS is broad, in that it proposes to eventually cover all major categories of emissions (i.e. forestry, transport, stationary energy, industrial process, agriculture and waste) and all six GHGs covered by the Kyoto Protocol. There is a phased implementation process (Table 1), so that ‘by the start of 2013 all major sectors will be exposed at the margin to the international price of emissions at the margin for all operations’ (MfE and NZ Treasury, 2007: 6). Like the EU ETS, the NZ scheme will be based on a domestic unit, the New Zealand Unit (NZU). The NZ ETS will be open to some form of bi-lateral or multilateral trading. Each NZU will be backed by an AAU and Kyoto units[1] will be interconvertible with NZUs, although with some limitations (MfE and NZ Treasury, 2007: 46).

Table 1 – Summary of coverage and phased implementation of NZ ETS

Sector	**Entry**	**Gases**	**Comments**
Forestry (pre-1990)	Jan 2008	CO_2	Emissions from change of land use (no liability if forest is replanted). Free allocation of 21Mt CO_2, and from 2013, an additional 34Mt CO_2.
Forestry (post-1989)	Jan 2008	CO_2	Forest owners may opt-in, in which case there is a credit/liability for net changes to carbon stocks.
Liquid fossil fuels (primarily transport)	Jan 2009	CO_2 (incl. end-use emissions)	No assistance to upstream points of obligation
Stationary energy (coal, gas, geothermal)	Jan 2010	CO_2	None to fuel producers/importers and electricity generators. Possible assistance to industrial producers for stationary energy and electricity use.
Industrial process emissions	Jan 2010		90% of 2005 emissions (incl. indirect emissions from electricity use)
Agriculture	Jan 2013	CH_4, N_2O (see main text)	90% of 2005 emissions, declining linearly to zero in 2025
Waste and all other emissions	Jan 2013	CO_2	No assistance for landfills

In the initial stage (2008–2012), substantial assistance will be provided to industries likely to be negatively affected. This will probably be through the free allocation of units, with remaining units to be auctioned. The government intends to progressively remove assistance between 2013 and 2025. While the final details remain to be seen, in-principle decisions have been made regarding entry into the scheme and

[1] Kyoto units include not only AAUs, but also: ordinary (CER), short- (tCER) and long- (lCER) term certified emission reductions from Clean Development Mechanism (CDM) projects; emission reduction units (ERUs) from joint implementation projects in Annex B countries; and removal units (RMUs) from net removals by LULUCF sinks in Annex B countries. Any of these units can be used by Annex B countries to meet first period commitments.

levels of assistance. The framework outlines alternative approaches of ‘free allocation’ or ‘progressive allocation’ and six ‘allocation principles’ that will be applied to determine the level and type of assistance applied in each sector (MfE and NZ Treasury, 2007: 65-7). ‘Free allocation’ is only loosely defined and might cover emissions-based grandfathering and many forms of benchmarking (although the document hints at a preference for grandfathering with no updating). Thus, with free allocation, firms would be immediately exposed to the full opportunity cost of their emissions, which would vary according to the price of NZUs. Progressive obligation refers to *ex-post* emissions-based allocation and would effectively subsidise each NZU required by firms to cover their emissions, reducing the opportunity cost of emissions by the extent of the subsidy (e.g. under 20% obligation, the opportunity cost per tonne of emissions is 20% of the NZU price).

Agricultural emissions to be covered by the NZ ETS are N_2O from synthetic fertilisers use, enteric CH_4, and emissions from manure management. In the 2005 inventory, these account for 4.7%, 63.9%, and 2.1% of total agricultural emissions respectively (Table 3). The government’s preferred points of obligation for agricultural emissions are meat and dairy processors, and fertiliser manufacturers, mainly because it avoids the complications of measurement, verification and administration of farm-level obligations. Fertiliser manufacturers have argued that this does not incentivize alternative reduction methods on-farm, such as denitrification inhibitors{Graham, 2007 #3473: 3(Graham, 2007: 3)}. Free allocations may be granted either to farms, processors, or sector bodies. The document allows that progressive allocation ‘could also be an option to consider for the agricultural sector’ (MfE and NZ Treasury, 2007: 65).

Unlike energy and industrial emissions, there are not proven technologies for abating most emissions from pastoral agriculture. This is problematic for New Zealand, given that almost half the country’s GHG emissions come from agriculture and that this sector has been and is still a mainstay of the economy. This is despite New Zealand having the lowest agricultural subsidies among OECD nations (OECD, 2007), and its farmers being exposed to international market pressures and fluctuating exchange rates. In 2005, the agriculture industry contributed $5.6 billion (approximately 4.5%) to New Zealand’s GDP and employed 82,440 people (over 2% of the population). Exports of food and fibre products consistently contributed more than 45% to total export earnings between 1985 and 2005 (Ballingall and Lattimore, 2004), and high reliance on these exports is expected for the foreseeable future.

Economic drivers have been influential on land use change and agricultural emissions in NZ. During the late 1970s and early 1980s government subsidies encouraged large scale conversion of marginal land into farming. Since subsidies were removed, market prices have driven land use change. High returns in dairy farming have resulted in an increase in dairy cattle from 3.4 million in 1990 to 5.2 million in 2006. Over the same period, sheep numbers fell from 57.9 to 40.1 million, but beef cattle numbers were stable at around 4.5 million. At the same time, there has also been widespread intensification in the pastoral sector. Higher emissions per dairy cow and increased use of fertilisers and energy for irrigation and other purposes in intensified farming systems, have increased overall emissions from the agricultural sector.

Forestry is the first sector to be included in the ETS. Pre-1990 forest and post-1989 forests are treated differently. Including emissions from deforestation of pre-1990 forest should reduce the sale value of this land, as it makes changing the land use costly. The free allocations are intended to partially compensate for this. Increased allocations from 2013 reflect the age profile of this forest stock. For post-1989 forest, credits are gained for net increases in stocks, and, liabilities are incurred for net decreases. At steady-state and in the long-term, the quantity (but not necessarily the value) of these credits and liabilities cancels out. However, the age profile of the current forest stock means that over the first commitment period the current forested area is a net sink. Conversions to forestry will increase this sink, while conversions from forestry will decrease it. There are exemptions for pre-1990 holdings under 50ha, deforestation of less than 2ha in a commitment period, and for weed control (MfE and NZ Treasury, 2007: 74).

Agricultural emissions and LULUCF in New Zealand

Agricultural emissions of CH_4 and N_2O in 2005 are shown in Table 2. Most of the emissions (90.8%) come from all forms of sheep, beef and dairy farming (italicised). Deer farming accounts for 2.7%, while all other forms of farming, horticulture and forestry account for the remaining 6.5%. Estimated emissions are distinguished by source in Table 3. A notable feature is the difference between the emission profiles of predominantly extensive sheep-beef, sheep, and beef farming on the one hand, and increasingly intensive dairy farming on the other hand. Emissions from fertiliser application account for only 2.4% of the total for sheep and beef (combined), while they account for 9.0% of the total for dairy. The dairy sector also has relatively higher emissions from waste and manure management.

Table 2 – Agricultural GHG emissions by detailed sector (own calculations, based on Statistics New Zealand, 2003; Ministry for the Environment, 2007)

ANZSIC industry[2]	ANZSIC code	CH_4 (kt CO_2-eq)	N_2O (kt CO2-eq)	Total (kt CO2-eq)
Sheep Farming	A012400	9349	4305	13698
Dairy Cattle Farming	A013000	7938	4567	12653
Beef Cattle Farming	A012500	3292	1488	4798
Sheep-Beef Cattle Farming	A012300	1534	721	2263
Deer Farming	A015300	681	312	997
Services to Agriculture n.e.c.	A021900	351	165	522
Mixed Livestock	A015910	335	163	502
Vegetable Growing	A011300	165	134	300
Pig Farming	A015100	161	23	216
Grain-Sheep & Grain-Beef Cattle Farming	A012200	101	79	181
Grain Growing	A012100	80	98	179
Poultry Farming (Meat)	A014100	58	28	170
Forestry	A030100	86	51	138
Other agriculture	—	246	140	387
TOTAL	—	24377	12274	37004

[2] Australian and New Zealand Standard Industrial Classification

Table 3 – Detailed emissions of top agricultural emitters (kt CO2-eq) (own calculations, based on Statistics New Zealand, 2003; Ministry for the Environment, 2007)

	Sheep-Beef Cattle Farming	Sheep Farming	Beef Cattle Farming	Dairy Cattle Farming	All other	Total
Anaerobic lagoon (N_2O)	0.2	0.5	0.4	12.4	2.5	16.0
Solid storage and dryplot (N_2O)	0.1	0.2	0.1	1.0	8.4	9.8
Other management systems (N_2O)	0.0	0.1	0.1	0.4	35.5	36.0
Direct soil (animal waste) (N_2O)	1.7	4.4	3.0	100.6	80.1	189.8
Animal production (grazing animals) (N_2O)	469.8	2907.3	990.5	2461.3	634.0	7462.9
Enteric fermentation (CH_4)	1511.8	9233.3	3243.4	7610.6	2029.5	23628.6
Manure management (CH4)	21.1	108.5	46.2	321.6	231.6	729.0
Leaching (manure) (N_2O)	82.6	509.7	174.0	452.7	128.5	1347.5
Deposition (manure) (N_2O)	94.4	582.6	198.9	517.4	146.8	1540.0
Direct soils (fert) (N_2O)	56.4	232.0	95.0	867.9	217.3	1468.6
Leaching (fert) (N_2O)	11.0	45.1	18.5	168.8	42.2	285.6
Deposition (fert) (N_2O)	6.3	25.8	10.6	96.4	24.1	163.2
Field burning (N_2O)	0.4	2.3	0.8	2.0	0.6	6.1
Field and savannah burning (CH4)	1.3	7.3	2.6	6.3	1.8	19.2
N-fixing crops (N_2O)	1.2	7.1	2.5	6.1	1.7	18.6
Crop residues and histols (N_2O)	5.3	31.9	11.2	27.3	7.8	73.4
TOTAL	2263.2	13698.1	4797.7	12652.9	3592.4	37004.3

The land use, land use change and forestry (LULUCF) section of New Zealand's inventory (Table 4) is dominated by net removals from forests. Other components of LULUCF currently make only a small net positive contribution to the total. Not all of the forestry in Table 4 is attributed to the forestry sector, because of the importance of farm forestry and the classification of enterprises in the industry classification scheme by their primary activity.

Table 4 – Land use, land use change and forestry (own calculations, based on Statistics New Zealand, 2003; Ministry for the Environment, 2007)

ANZSIC industry	Forestry	Lime	Grassland	Cropland Conversions	Total[3]
Other horticulture	-65.2	16.8	4.5	-41.9	-85.6
Apple and pear growing	-31.7	1.4	0.4	-0.9	-30.7
Kiwifruit growing	-41.3	2.2	0.5	-1.2	-39.7
Other fruit growing	-43.9	3.8	1.1	-4.0	-42.8
Mixed livestock and cropping	-456.8	25.0	12.5	-141.7	-560.0
Sheep and beef cattle farming	-5918.4	369.6	532.9	-333.5	-5340.6
Dairy cattle farming	-1074.5	256.0	164.4	-58.4	-711.3
Other farming	-241.1	27.6	28.0	-31.2	-216.4
Services to agriculture, hunting & trapping	-18.0	4.4	6.5	-4.2	-11.3
Forestry	-16020.9	2.2	5.5	-6.8	-15993.5
TOTAL	-23911.8	709	756.3	-623.8	-22934.7

[3] Scaled, to account for minor omissions in the accounts illustrated.

Practically all timber is now produced from planted exotic forests, of which about 90% are *Pinus radiata*. The forestry net removals depend on the size and age structure of the forest stock. Over the last 30 years afforestation and reforestation has averaged 43 000 ha per year. This rose to 69 000 ha/yr over 1992–1998 but has fallen to only 6 000 in 2005 (Ministry for the Environment, 2007: 76).

Modelling prices under GHG taxes or cap-and-trade

An industry-by-industry input-output table relates production to levels of final demand, and industry prices to factor and import prices, and taxes on products and production. Specifically, output prices are determined by Leontief cost functions, in which inputs are combined in fixed proportions. The Leontief price model is the dual of the better known quantity model, which has been widely used to analyse relationships between final demands and environmental pressures, including emissions of greenhouse gases (e.g. Lenzen, 1998, 2002). IO models have also been used to estimate price effects of CO_2 taxes on prices in countries including the UK and Germany (Proops *et al.*, 1993; Symons *et al.*, 1994), Canada (Hamilton and Cameron, 1994), Australia (Cornwell and Creedy, 1996), Spain (Labandeira and Labeaga, 1999) and more recently, New Zealand (Creedy and Sleeman, 2006). These studies have focussed particularly on distributional impacts on households, supplementing IO analyses with either household microsimulation techniques or econometrically estimated expenditure functions.

Computable general equilibrium (CGE) models and partial equilibrium (PE) models provide alternative means of studying price impacts of carbon or GHG taxes. IO models are considerably simpler than CGE models, facilitating more detailed representations of the productive and household sectors. The latter is particularly important to the study of distributional impacts. The Leontief cost functions do not model possibilities for substitution in production (of fuels, other intermediate and factor inputs), but this inflexibility may often be an appropriate representation, especially for relatively homogenous industries and in the short run. Scrimgeour *et al.* (2005) have used a CGE model to assess efficiency and distributional impacts of petroleum products, energy and carbon taxes in New Zealand. Infometrics Ltd. (2007) have modelled the impacts of the NZ ETS for several exogenous carbon prices and different scenarios for the post-Kyoto period. The latter scenarios include a price on methane and nitrous oxides, but the agricultural sector is represented at a high level of aggregation.

PE models focussed on particular sectors within the economy and facilitate very detailed representations of technologies. However, these models do not capture the economy-wide linkages and consequent indirect price effects, which are particularly important in the case of energy-related emissions. Saunders *et al.* (Saunders et al., 2006) extend the 'Lincoln Trade and Environment Model' (LTEM) to model GHG emissions from the dairy sector, and analyse the impacts of EU and OECD trade reforms on outputs, prices and emissions in New Zealand and the EU. This model could be extended to model the direct impacts on agriculture of inclusion within the NZ ETS, given an NZU price.

Hendy *et al.* (2006) use the LURNZv1-climate model (a spatial microeconometric model of primary production sectors focussing on land use) to explore the impacts of a high charge of NZ$50/t CO_2-eq on agricultural emissions (assuming fixed per-hectare emission factors). They find that from 2003–2012, this causes an 11% reduction of dairy farm revenues and a 1% contraction of area compared to a baseline increase of 1.2%. Impacts for sheep and beef are worse, with a 22% reduction of revenue and an additional 0.3% contraction in area. There are negligible effects on the baseline 17% expansion of forestry. The resulting emissions are reduced 6% over the first commitment period relative to the baseline, and the authors conclude that this is not a cost-effective policy, although suggest that more targeted policies considering stock numbers and fertiliser use might perform better.

None of the aforementioned New Zealand studies consider specific mitigation technologies (excepting simple fuel and electricity substitutions in both the CGE models). Brink and Idenburg (2007) show mitigation technologies for CO_2 and NO_x can be modelled by using IO functions within a cost minimisation framework. Mitigation technologies (including management practices) in agriculture are likely to be very important for New Zealand, but little is yet know of their costs and effectiveness.

2 Method

The Leontief price model, derived from industry by industry input-output tables, relates relative prices of sector output *p* to primary input costs shares *B* at prices *f*, via a matrix of direct input cost coefficients *A*:

$$p^T = f^T B(I - A)^{-1} \qquad (1)$$

Quantities are usually defined in terms of base year values, meaning that the initial prices are unity. The model simulates a pure cost-push effect, with prices equal to total average costs. In the basic IO model, the matrix *B* has rows for compensation of employees, depreciation, gross operating surplus, taxes on production, taxes on commodities, and subsidies. To analyse the impact of pricing GHG emissions, this matrix can be extended with coefficients B_g for the intensity of different GHG emissions in tonnes CO_2-eq per NZ$m (2). We distinguish emissions from use of liquid fuels for transport[4], emissions from electricity generation, emissions from other stationary energy, industrial emissions, and agricultural emissions. In effect, the prices of these emissions (*g*) are currently zero.

$$p^T = \begin{bmatrix} f \\ g \end{bmatrix}^T \begin{bmatrix} B_f \\ B_g \end{bmatrix} (I - A)^{-1} \qquad (2)$$

It is inappropriate to include forestry sequestration in these cost functions, as this is not directly related to current output. For this reason, we consider this aspect of the ETS only qualitatively.

Since this model is linear and initial prices are defined to be unity, we consider only the change in prices, which is equal to:

$$(\Delta p)^T = \begin{bmatrix} 0 \\ g \end{bmatrix}^T \begin{bmatrix} B_f \\ B_g \end{bmatrix} (I - A)^{-1} \qquad (3)$$

[4] Liquid Petroleum Gas used for transport is included in the ETS together with Natural Gas as part of 'stationary energy' stage.

The vector *g* should now represent the opportunity cost associated with each category of emissions, assuming that there are no further distinctions made between sectors. In the simplest case the opportunity cost is equal to the average market price for an NZU, then g is simply a vector containing zeros for emissions that are not covered by the ETS, and the NZU price for emissions that are covered. Intermediate values of g could be used to reflect partial obligations (i.e. NZUs are required to cover only a specified percentage of total emissions). Sector-specific details could easily be incorporated by modifying the matrix B_g.

The matrix *A* is derived from a 123 sector inter-industry transactions table for the year ending March 2004. That table is the result of updating original survey-based tables for 1995-96 (Statistics New Zealand, 2001) using a variety of sources (McDonald, 2007, pers. comm.). GHG emissions from energy use by sector are estimated from EECA database 2002, various editions of the Energy Data File and applying standard emission factors[5]. Other GHG emissions by sector are sourced from the National Emissions Inventory (Ministry for the Environment, 2007), including unpublished data. For agricultural sectors, more detailed GHG inventory data were generally aggregated to the level of the IO sectors. For some sectors (including within horticulture), energy and GHG inventory data had insufficient sectoral detail, and in these cases were allocated in proportion to sectoral output. Miller and Blair (1985) is a standard reference on the derivation of economic and environmental coefficient matrices in IO analysis.

Our application of the model (3) assumes that there are no changes in other factors prices. In fact, even considering only a cost-push effect in production, general equilibrium effects will cause some adjustments in prices of primary inputs. For low to moderate NZU prices, effects on prices of labour and capital should be extremely small. However, more significant price impacts may be expected in the case of land used in agriculture and forestry, as is discussed below. It would be possible to introduce additional variables for sector-specific land prices, fixing the corresponding output prices. However, we do not do this because prices for the same goods (or at least goods from the same IO sector) may be passed on much more easily in domestic markets than in export markets increases in domestic markets, especially where there is limited competition from imports (e.g. consider the export of milk powder vis-à-vis the supply of fresh milk domestically). Thus, it is useful to model the indirect effects of price increases even in such sectors, although the modelled prices will not reflect the average prices of industry output.

Direct costs are calculated by applying a price to the direct emissions of each sector that are within the scope of the ETS. In addition to the actual direct emissions of sectors, those associated with electricity use are also allocated to users, with only emissions associated with self-use and losses being allocated to the electricity generation sector itself. It is preferable to allocate emissions this way in the IO model, because of price and product heterogeneity within sectors[6]. For example, price heterogeneity occurs because of

[5] These data are available respectively from the Energy Efficiency and Conservation Authority (www.eeca.govt.nz), Ministry of Economic Development (www.med.govt.nz), and from the authors on request.
[6] A further benefit of this approach is that to reduce aggregation bias associated with the electricity sector. The source IO tables include substantial electricity retailing activity within the electricity generation sector, because many of the companies in this sector are vertically integrated. Vertically integrating industries in the price model

discounting for bulk and off-peak electricity users. Product heterogeneity is for sectors producing fuels and fertilisers, which are used by industries in different proportions, and have different GHG emissions intensities.

Costs are calculated for the five major categories of sectors/emissions to be covered by the ETS. Whether emissions are priced up- or down-stream has no effect on downstream prices in the model, but it does mean that upstream sector prices (for e.g. electricity) are not representative of the corresponding market prices. Actual upstream prices can be recovered by adding to the modelled upstream prices the direct costs of any emissions allocated downstream. Net credits or liabilities for LULUCF in each sector (most importantly, credits for afforestation) are not modelled. The main reason for this is that the credits are not simply proportional to sectoral outputs. Inclusion of forestry in the ETS is likely to affect prices in forestry and other sector through several mechanisms though, as discussed further below.

A price of NZU of NZ$25/t CO_2-eq is used for modelling in this paper. This value has been widely used in studies and discussions of the ETS (e.g. Infometrics Ltd, 2007). Given that in the model, output prices will vary in direct proportion to the NZU price (assuming the same price applies equally to all emissions), the effects of other NZU prices may be seen by simply scaling the results accordingly. However, the interpretation of the results may differ significantly for much lower or higher prices.

Results

The price model is used to estimate pure cost-push effects on New Zealand food and fibre prices as GHG pricing is extended throughout the economy (Table 5). Emissions are included sequentially beginning with liquid hydrocarbons (1), then electricity generation (2) and other stationary combustion (3), industrial emissions (4) and finally agricultural emissions (5). The price increases shown in Table 5 would be required if the opportunity cost of direct and embodied emissions, at current emissions intensities and $25/t CO_2-eq, were not to be absorbed by producers. However, as will be discussed further below, partial and general equilibrium effects and exposure to international competition make this unlikely. The results should rather be seen as indicative of potential short-term cost pressures on primary and downstream processing sectors as the ETS is phased in.

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causes a bias in downstream price effects when compared to a more disaggregated model (Olsen, 2002). However, with downstream allocation, only emissions costs associated with electricity self-use and generation losses are affected by the bias.

Table 5 - Cost-push effects of ETS on NZ food and fibre sector prices (% change)

	Stage of ETS (2–4 are simultaneous)				
	1	**2**	**3**	**4**	**5**
Other horticulture	0.25%	0.30%	0.34%	0.38%	**1.57%**
Apple and pear growing	0.26%	0.32%	0.36%	0.41%	**1.01%**
Kiwifruit growing	0.25%	0.31%	0.34%	0.38%	0.89%
Other fruit growing	0.26%	0.31%	0.35%	0.40%	**1.27%**
Mixed livestock and cropping	0.22%	0.26%	0.30%	0.34%	**3.09%**
Sheep and beef cattle farming	0.25%	0.30%	0.34%	0.39%	**11.17%**
Dairy cattle farming	0.24%	0.29%	0.34%	0.37%	**5.90%**
Other farming	0.25%	0.30%	0.34%	0.42%	**5.42%**
Services to agriculture, hunting and trapping	0.26%	0.31%	0.36%	0.43%	**1.88%**
Forestry	0.52%	0.55%	0.58%	0.64%	**1.03%**
Services to forestry	0.21%	0.23%	0.27%	0.33%	0.43%
Logging	**1.09%**	**1.12%**	**1.15%**	**1.22%**	**1.39%**
Meat processing	0.27%	0.35%	0.48%	0.53%	**6.09%**
Poultry processing	0.21%	0.28%	0.42%	0.46%	**1.63%**
Bacon, ham and small-good manufacturing	0.16%	0.24%	0.42%	0.46%	**1.72%**
Dairy product manufacturing	0.23%	0.32%	0.72%	0.77%	**4.82%**
Fruit & vegetable, oil & fat, cereal & flour manufacturing	0.18%	0.24%	0.35%	0.40%	0.83%
Textile manufacturing	0.18%	0.24%	0.38%	0.43%	**2.47%**
Log sawmilling & timber dressing	0.37%	0.59%	0.81%	0.87%	**1.11%**
Other wood product manufacturing	0.21%	0.49%	0.76%	0.84%	**1.02%**
Paper & paper product manufacturing	0.18%	0.54%	0.68%	0.74%	0.84%

The first stage of the ETS includes only liquid fuels. There is likely to be a high pass-through rate for these costs because (pre-ETS) New Zealand fuel prices are largely determined by the world market. While the domestic market is relatively concentrated, there is no compelling evidence of non-competitive pricing. For most industries, these costs are passed on via direct input of fuels, and purchase of road freight transport. Pass-through of costs in freight transport is also likely to be high. For this and subsequent stages of the ETS, Table 6 shows the contribution of own emissions (allocated downstream) to total cost increases, while Table 7 shows the contribution of road freight services to total cost increases.

Table 5 shows that cost pressures on agricultural sectors are relatively slight in the first stage (0.22–0.26%). The impacts are relatively uniform, although the aggregation level of the IO model and underlying data may mask some heterogeneity of cost impacts. Direct fuel use accounts for at least half of the cost increases (Table 6), while road freight accounts for a further 20–24% (Table 7). Road freight cost impacts for dairy farming are less significant, possibly because milk collection is mainly performed by the dairy processing sector. Cost pressures downstream are slightly worse for meat processing, but slightly less for all other downstream sectors. This is due to the relatively lower amount of CO_2 emissions from fuels per dollar output of these processing sectors. Costs in the forestry sector increase most significantly (disregarding any possible effects related to LULUCF credits). Cost increases are most significant for the logging sector, mainly due to its own fuel use (88%) for the operation of logging trucks and machinery. However, cost impacts are substantially mitigated even after the first step of processing (0.37% for timber milling and dressing) and are still less further downstream (0.21% for other wood product manufacturing and 0.18% for paper and paper product manufacturing).

Table 6 – Own emissions (incl. emissions from electricity used) as percentage of total price increase

	Stage of ETS (2–4 are simultaneous)				
	1	**2**	**3**	**4**	**5**
Other horticulture	62%	62%	59%	56%	60%
Apple and pear growing	58%	58%	55%	53%	37%
Kiwifruit growing	62%	61%	58%	56%	40%
Other fruit growing	59%	59%	57%	54%	48%
Mixed livestock and cropping	59%	58%	55%	50%	67%
Sheep and beef cattle farming	51%	51%	48%	44%	81%
Dairy cattle farming	75%	74%	69%	64%	90%
Other farming	60%	60%	56%	56%	88%
Services to agriculture, hunting and trapping	63%	62%	58%	55%	60%
Forestry	4%	4%	4%	5%	14%
Services to forestry	31%	28%	24%	23%	18%
Logging	88%	86%	83%	80%	70%
Meat processing	5%	14%	31%	29%	3%
Poultry processing	7%	17%	36%	33%	9%
Bacon, ham and small-good manufacturing	9%	21%	36%	33%	9%
Dairy product manufacturing	12%	22%	60%	57%	9%
Fruit & vegetable, oil & fat, cereal & flour manufacturing	18%	23%	36%	33%	16%
Textile manufacturing	23%	29%	45%	43%	8%
Log sawmilling & timber dressing	3%	35%	48%	46%	36%
Other wood product manufacturing	5%	42%	51%	47%	39%
Paper & paper product manufacturing	7%	58%	60%	58%	51%

Table 7 – Road freight prices as percentage of total cost increase

	Stage of ETS (2–4 are simultaneous)				
	1	**2**	**3**	**4**	**5**
Other horticulture	21%	18%	16%	14%	3%
Apple and pear growing	23%	19%	17%	15%	6%
Kiwifruit growing	22%	18%	16%	14%	6%
Other fruit growing	24%	20%	18%	16%	5%
Mixed livestock and cropping	20%	17%	15%	13%	1%
Sheep and beef cattle farming	20%	16%	14%	13%	0%
Dairy cattle farming	10%	8%	7%	7%	0%
Other farming	24%	20%	17%	14%	1%
Services to agriculture, hunting and trapping	19%	16%	14%	12%	3%
Forestry	65%	63%	59%	54%	33%
Services to forestry	35%	32%	27%	23%	17%
Logging	6%	6%	6%	6%	5%
Meat processing	45%	35%	26%	23%	2%
Poultry processing	45%	33%	22%	20%	6%
Bacon, ham and small-good manufacturing	50%	33%	19%	17%	5%
Dairy product manufacturing	15%	11%	5%	5%	1%
Fruit & vegetable, oil & fat, cereal & flour manufacturing	43%	33%	22%	20%	10%
Textile manufacturing	39%	30%	19%	17%	3%
Log sawmilling & timber dressing	65%	41%	30%	28%	22%
Other wood product manufacturing	63%	27%	18%	16%	13%
Paper & paper product manufacturing	68%	23%	18%	17%	15%

Broadening the scheme to include electricity generation (stage 2) causes additional costs greater than 0.1% only for the three wood and paper processing sectors (an additional 0.22%–0.35%). Other stationary generation is included simultaneously. This again has minor impacts on agriculture, but affects most processing sectors more significantly. The greatest increases are for bacon, ham and small good manufacturing (this sector is small and fuel data are relatively unreliable), and for dairy product manufacturing, where pricing emissions from stationary energy increases costs by 0.17%. Inclusion of industrial emissions increases costs by a further 0.04% and 0.08%, with higher values generally for the processing sectors. These costs may be exaggerated, since we have included all industrial emissions in the national inventory. In practice, the scope of the ETS may be limited due to the large number and diversity of small and medium source concerned that must be considered. Also, SF_6 is specifically excluded until 2013. At this point, total cost increases for all agricultural sectors remain below 0.4%. Costs downstream are now slightly higher. The largest industries, meat and dairy processing suffer cost increases of 0.52% and 0.54% respectively. Forestry and downstream industries remain worst affected, with cost of the latter increasing from 0.71% to 0.76%.

By far the most significant impacts of the ETS on food and fibre sectors will be felt in 2013, when agricultural emissions are to be included. The total cost increases for a majority of these sectors are above 1%; however, the most dramatic impacts are felt exclusively in the sectors related to ruminant animals. The backbone sectors of sheep and beef farming and dairy farming suffer cost increases of 11.2% and 5.9% respectively. The higher impact on sheep and beef compared to dairy is due mainly to the higher value of dairy production per animal. These costs are again mitigated at the processing stage, with increases of 6.1% and 4.6% respectively. Nevertheless, these are significant cost pressures, even in the context of exchange rate fluctuations and the substantial trade barriers to NZ imports into the EU and USA.

Discussion

Pricing GHG emissions has two aims. It should stimulate reductions in emissions intensity of production and changes in compositions of intermediate and final consumption, so as to decrease consumption of more GHG-intensive products. Industry-average emissions intensity (defined for the present purposes as kt CO_2-eq per $m output) can be cut by reducing emissions intensity at firm/farm level, and by changes in output or entry/exit of firms/farms with differing GHG efficiencies. While these two effects are equally capable of lowering emissions intensity, they are likely to differ in other important respects (e.g. substantial industry turnover may cause loss of human capital, loss of investment confidence and disruption to small communities).

Prospects for technical mitigation of agricultural emissions

There are a wide range of options that may allow reductions in agricultural GHG intensities, especially in the longer term (see e.g. Garnett, 2007). However, it is difficult to estimate their real potential as they are as yet unproven. As a result there is limited information on their practical effectiveness and costs, and just how regionally specific these are likely to be. One question that arises in Europe, but not in New Zealand's pasture-based systems, is the efficiency of different intensive feeding and housing systems. Animal breeding and other measures to increase fertility in breeding stock, milk-solids output for dairy cows, and shorten fattening periods (for meat production) may help reduce emissions. These are generally compatible with maximising profit.

Nitrification inhibitors such as Dicyandiamide (DCD) and 3,4-Dimethylpyrazole Phosphate (DMPP) show promise for mitigating N_2O emissions from intensive grazing systems (Suter et al., 2006). Suter et al. review experimental studies in which N_2O reductions of 61–91% and pasture yield increases of 0–36% are achieved. Nitrification inhibitors may also reduce nitrate leaching, and hence groundwater contamination, which is a major problem in some areas of New Zealand. However, there remains much uncertainty about their effectiveness at the farm scale and in long-term use.

Mitigation of ruminant methane emissions is possible through general increase of dietary efficiency and by specific dietary manipulations. The latter seek to improve animals' fermentation of fibre (which produces CO2, H_2 and volatile fatty acids as end products) and/or to reduce subsequent methanogenesis (which produces CH_4 from CO_2 and H_2). In New Zealand, productivity improvements in the dairy industry from 1990 to 2003 have reduced product emission intensity from 8.4 to 6.6kg CO_2-eq/kg milk solids (p96, MfE and NZ Treasury, 2007). Nevertheless, over the same period, total agricultural emissions have increased at 1% per year. There is extensive experimental research into the use of different pasture cultivars and feed additives. As yet, none of these options appear to provide cost-effective GHG mitigation for extensive grazing systems (Waghorn and Clark, 2006). For intensive grazing systems, emissions intensity may be reduced by a combination of pasture improvement, management and animal selection (Waghorn and Clark, 2006).

While waste treatment and manure management makes only a slight contribution to total agricultural emissions, these are sources of emissions that may be more amenable to mitigation by applying proven technologies.

Increased efficiency and substitution of energy and other inputs to agriculture

As well as reducing their direct emissions intensity, industries may also be able to mitigate against GHG-related cost increases by reducing use of or substituting for other inputs that have high embodied GHG emissions. Such measures are rarely considered except in specialised studies. In partial and general equilibrium models, energy substitutions are sometimes considered, although infrequently with particular attention to agriculture. Other inputs are usually considered only in the aggregate, if at all. The significance of freight transport for many sectors suggests that increasing logistical and fleet efficiency may be worthwhile.

Partial and general equilibrium effects

Land use changes between farm systems and between farming and forestry systems are likely to be important avenues for reducing overall NZ emissions. Native reforestation (which would generate carbon credits) and possibly bioenergy production may also play a role. Land use decisions of individual landholders depend on many factors (e.g. experience, attitude to risk, lifestyle preferences), but an important driver is the expected returns per hectare from alternative activities. Sheep, beef and dairy production are highly export-oriented, with 64% and 72% of output by value driven ultimately by export demand in 2004, and meat and dairy products accounting for 12% and 13% respectively of NZ exports. There is little ability to pass on costs in this sector, thus they will largely be borne by farmers, particularly through reductions in land values.

While not included in the analysis above, treatment of credits and liabilities associated with pre-1990 and post-1989 forests are also likely to affect land values and land use change. In particular, it creates a cost for converting forest to other uses, so should slow deforestation of at least pre-1990 forests. For example, it may prevent planned conversion to dairy pasture of 14,000 ha of Wairakei Estate (CCMAU, 2007). While the ETS should increase afforestation, the net effects are very sensitive to assumptions on future emissions prices and investors' risk-adjusted discount rates (see e.g. MfE and NZ Treasury, 2007: 118). An interesting finding of this study is that there are potentially greater (although still quite small) cost impacts on the forest sector compared to those faced by agricultural sectors, which may work against the policy objective until agricultural GHGs are included.

A possible undesirable consequence of changes in land use may be 'emissions leakage'. This means that output is reduced (or increased less than otherwise) because New Zealand producers face higher marginal costs than in other producing countries. If the countries that produce the shortfall in demand have higher GHG emissions per unit output, the ultimate objective of ETS will not be met. In this context, it is important to note that the costs above are in domestic currency. A factor often ignored in arguments about international competitive risk is that reduced exports will tend to weaken the currency and help to mitigate the impact of domestic price rises. Unlike capital in industrial sectors, farm and forest land (of different qualities) is of course immobile. Nevertheless, costs of the ETS may still cause leakage of agricultural emissions if moving land out of emissions-intensive (i.e. ruminant) production systems in New Zealand encourages compensating increases in ruminant production in other countries where producers do not bear emission costs. Greenhalgh *et al.* (2007) discuss trade exposure and leakage in relation to the NZ ETS in some detail. Those authors suggest that border tax adjustments (BTA)[7] selectively applied to trade-exposed emissions-intensive products could be an effective policy, especially if coordinated with other countries. Alternatively, or pending introduction of a BTA, output-based allocations (i.e. where free allocations are made proportional to current or recent years' output, rather than to a benchmark year/s output) would be a simpler instrument that could also effectively reduce carbon leakage. Certainly, negative impacts of the ETS would be substantially less if major export competitors also instituted emissions pricing. Equally, they might be reduced if major importers such as the EU implemented emissions pricing with BTA, or alternatively, a consumption tax on 'embodied' agricultural emissions.

[7] Taxing imports and rebating exports such that domestic and foreign producers are treated equally in both domestic and foreign markets.

3 Conclusions

In the first stage of the ETS, the effects of a $25/t carbon price are arguably insignificant for New Zealand's food and fibre industries, at least in the context of other changes in their economic environment. Prior to the inclusion of agricultural emissions in 2013, emissions pricing also has a rather uniform impact on the different agricultural sectors, although the aggregation level of the model and underlying data may mask some heterogeneity. Forestry is relatively more strongly impacted by pricing of emissions from liquid fuels. Farming and forestry are less affected by the inclusion of emissions from stationary generation in 2010, but the downstream food and fibre processing industries see cost increases in the order of 2-3 times those from liquid fuels' inclusion.

Potentially more significant effects in the first five years will be result from the treatment of forestry sources and sinks. While these effects could not be quantified using the present methodology, qualitatively, they should involve increased afforestation or less deforestation. This may affect agriculture by putting further pressure on some marginal sheep and beef country (i.e. increasing the incentive to bring this land into forestry), and further constraining the amount of land available for the rapidly expanding dairy sector. Of course, over five years, changes in international prices for meat, wool, dairy and forest products might have much greater and perhaps entirely different effects.

Introduction of agricultural emissions in 2013 evidently is likely to have a relatively strong impact on ruminant-based farming systems, although the cost increases on-farm are significantly mitigated through the value-adding stages. For these sectors, technologies for direct mitigation of CH_4 and N_2O emissions is very important in the long term. Equally, pricing of agricultural emissions by other major producing countries, or pricing of embodied emissions by major importing countries could substantially mitigate negative effects on New Zealand agriculture, and consequent carbon leakage. Alternatively, reductions of current trade barriers to New Zealand exports in the EU and elsewhere could more than offset the negative effects of a $25/t carbon price; although New Zealand might be relatively disadvantaged against competing exporters with no emission costs, like Australia and Chile.

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