Socio-Economic Impacts of the Agricultural Emissions Trading Scheme

Levente Timar
Research Economist
Motu Economic and Public Policy Research
levente.timar@motu.org.nz

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a Very Preliminary Draft

Levente Timar*

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* Research Economist, Motu Economic and Public Policy Research, levente.timar@motu.org.nz

ABSTRACT

The impacts of including the agricultural sector in the New Zealand Emissions Trading Scheme (ETS) depend on how farmers change their behaviour in response to the increased cost of emissions. Yet most analyses of the ETS do not allow for a behavioural response. This paper partially addresses the gap in the literature: it allows for farmers to change their land use to reflect the reduced returns from pastoral agriculture as well as the potential to earn carbon credits for sequestration performed by plantation forestry and scrub. Simulations performed in the Land Use in Rural New Zealand (LURNZ) model allow us to answer questions about the likely spatial and temporal distribution of the socio-economic impacts of the ETS.

Introduction

Agricultural emissions make up about half of New Zealand's overall greenhouse gas emissions – a proportion unmatched by any other OECD country. The large fraction of emissions coming from agriculture is often given as justification for including the sector in the Emissions Trading Scheme (ETS), and it is also a testament to the economic significance of the agricultural sector to the country. Dairy products alone constitute about 25% of total merchandise export earnings in New Zealand. Potentially large changes in returns and economic incentives under the ETS and their socio-economic implications are therefore a matter of great interest to policy makers.

Ultimately, the socio-economic impacts of the ETS may significantly depend on how farmers change their behaviour in response to the increased cost of emissions and the ability to gain credit from plantation forestry and native forest sequestration. Farmers' ability to adapt varies by geographic region due to inherent differences in climate, land quality and infrastructure. Regions also differ with respect to the socio-economic characteristics of their population. Nevertheless, most analyses of the ETS are not spatially explicit, and those that are do not typically account for farmer's ability to adapt to the policy.

Sin et al (2005) and Zhang and Kerr (2010) study the regional economic impact of agricultural emissions policy by combining information on emissions charges with data on the socio-economic characteristics of the affected areas. This study extends their analysis in two (closely related) ways. First, it accounts for the financial implications of farmers' abilities to gain credit from plantation forestry or native sequestration. Second, it models farmers' abilities to change their land use in response to the reduced returns from pastoral agriculture and the increased returns from plantation forestry and scrub. This study thereby begins to partially address the gap in the literature. It does not address it fully because it does not allow for the full range of potential behavioural responses – for example, it does not yet allow farmers to change their land use intensity or mitigate their emissions. The study builds on the results of simulations performed in the Land Use in Rural New Zealand (LURNZ) model to answer questions about the likely spatial and temporal distribution of the socio-economic impacts of the ETS. The broad framework presented in this paper will in the near future be used to model the implications of different free allocation methods of emission permits and on-farm mitigation methods.

Brief Background on the LURNZ Model

LURNZ is a dynamic partial equilibrium model that simulates changes in rural land use over time and space. It is based on two interacting econometric models, and covers the four most important rural uses in New Zealand: dairy farming, sheep or beef farming, plantation forestry and an economically unproductive use, scrub. LURNZ excludes conservation or other public land, urban uses as well as all other types of rural land use such as horticulture.

The time-series module of LURNZ is based on dynamic singular system modelling (Anderson and Blundell, 1982). It estimates an econometric relationship between the national shares of the four modelled land uses and exogenous variables that include producer subsidy equivalent export prices for standardized products of all modelled sectors and the rate of interest. The rate of interest is included in the regression to control for general macroeconomic conditions. The model uses historical data from 1972 to 2008. For simulations of future scenarios, the model employs exogenous forecasts (from MAF) of the explanatory variables. A forthcoming Motu working paper (Olssen and Kerr, 2011) describes this part of the model in detail.

The spatial module of LURNZ is used to allocate the land use shares from the national-level time-series model spatially. The backbone of this module is a cross-sectional discrete choice model of land use, similar to Chomitz and Gray (1996), that estimates a statistical relationship between private land use decisions and various geophysical and climatic determinants of land quality (slope, land use capability class, net primary productivity), location (distance to population centres and commercial ports) and land tenure (Maori freehold title versus general private title). The model is based on the assumption that landowners compare potential economic returns under different land uses to devote each parcel to its highest-valued use. For every 25-hectare cell of private rural land, the model predicts land use decisions, in a probabilistic sense, based on the characteristics of the land and the attributes of the location (Timar, 2011). The spatial allocation algorithm supplements these land use probabilities with geographic information on forest age classes to model plantation forestry harvest decisions: trees cannot be harvested in the model before they reach a certain harvestable age.

The LURNZ model also includes additional modules to simulate the likely evolution of production intensity on dairy and sheep/beef farms. It models national trends in stocking rates and fertiliser use and combines these with geographic information on livestock carrying capacity and implied emissions factors to translate the results into spatially heterogeneous carbon dioxide-equivalent greenhouse gas emissions. It also produces maps of sequestration activity for forestry and scrub based on the sequestration rates of typical species and spatial information on forest age.

Its structure allows LURNZ to simulate any policy that can be modelled as a commodity price or interest rate shock and to empirically investigate the potential effects of policies designed to alter land use decisions. An emissions charge on methane and nitrous oxide and foresters' ability to earn credits for sequestration performed by their forests both satisfy this requirement. The framework is spatially disaggregated and therefore it enables the analysis of scenarios where the distribution of land uses matters. Interested readers are referred to Hendy et al. (2007) and the aforementioned Motu working papers for more information on the LURNZ model.

Methods

Producers are, in theory, able to shift the costs of a tax levied on them to their consumers (through higher output prices) or to their employees (through lower wages). Sin et al. (2005) argue that most New Zealand producers are price takers in international markets, and most of the impact of a carbon charge under the ETS is therefore likely to fall on producers rather than consumers. On the other hand, producers may be able to shift some of the costs to their employees. The indirect impacts will thus likely be localised to rural communities. Modelling land use and emissions in a spatially disaggregated manner in LURNZ enables the analysis of the impacts on these communities.

The strategy employed in this paper is to aggregate land use outcomes and emissions spatially at the scale of Labour Market Areas (LMAs). There are 58 LMAs in New Zealand and table 1 shows key socio-economic characteristics associated with each. The LMAs are defined so that most people who live in a LMA also work in it, and vice versa (Newell and Papps, 2001). Therefore, if producers are indeed unable to raise their output prices, but they are able to offer lower wages, the indirect impacts are likely to be largely constrained to the LMA in which the direct effects occur.

The approach taken in this paper is one of partial equilibrium. It focuses on changes in rural land use in response to the ETS (and the associated changes in net emissions) and relates these to the characteristics of the LMAs. It does not formally address any feedback effects or downstream effects on other economic sectors and the New Zealand economy as a whole. It also does not include interactions or spillovers within the agricultural sector. While the model partially accounts for farmers' ability to adapt (through land use change as opposed to changes in land use intensity), it does not account for workers' ability to adapt (through migration) when considering indirect impacts. It assumes that the full costs of the policy are borne by agents within the LMA in which the impacts occur.

The policy I consider in is a charge of $25 for each tonne of carbon dioxide equivalent emissions starting in the year 2015 (and a corresponding $25 credit for each tonne sequestered starting in 2008). These are converted into commodity price effects for modelling in LURNZ. The charge corresponds to a cost of approximately $0.15 per kilogram of milk solids produced, and $0.18 per kilogram of composite sheep and beef farming output produced, where the composite output consists of beef, lamb, mutton and wool (Olssen and Kerr, 2011). For the forestry sector, the charge is similarly converted into an effect (positive in this case) on log prices. These output price changes are expected to have an impact on farm profits that is similar in magnitude to the impact experienced in the 1980s after the removal of farm subsidies (Zhang and Kerr, 2009). The size of the modelled policy effect is therefore not outside the historical range, and the time-series data employed in LURNZ should be sufficient to reflect the expected land use responses.

To evaluate the effects of this policy, I initially run two scenarios in LURNZ. The first scenario assumes a $0 carbon price under the ETS. This is the baseline scenario: it simulates the land use outcomes in a world in which farmers do not change their land use decisions in response to the policy. The second scenario involves a $25 carbon price (without free allocation) and will therefore result in land use outcomes different from those in the first scenario.

Both scenarios are simulated until the year 2030. Commodity price forecasts do not cover the entire length of this period. Commodity prices are thus assumed to stay constant at their last forecasted values. Nevertheless, in both scenarios land use change occurs in each year throughout the period of simulation because the adjustment to equilibrium is not instantaneous.

National-level land use outcomes in the two scenarios are shown in figures 1 and 2. As expected, the land area devoted to plantation forestry is higher in scenario 2 and the area devoted to either type of pastoral farming is lower. Scrub area is also lower in the scenario involving land use change, reflecting the conversion to plantation forestry that takes place in response to the increased returns to this use. For illustration, the simulated geographic distribution of the land use outcomes under scenario 1 in 2030 is also reproduced in figure 3.

(Note that only dairy, sheep and beef farming, forestry and scrub are modelled – the other uses are exogenous and identical across the scenarios.)

Figure 1. The evolution of national land use areas if no behavioural response assumed

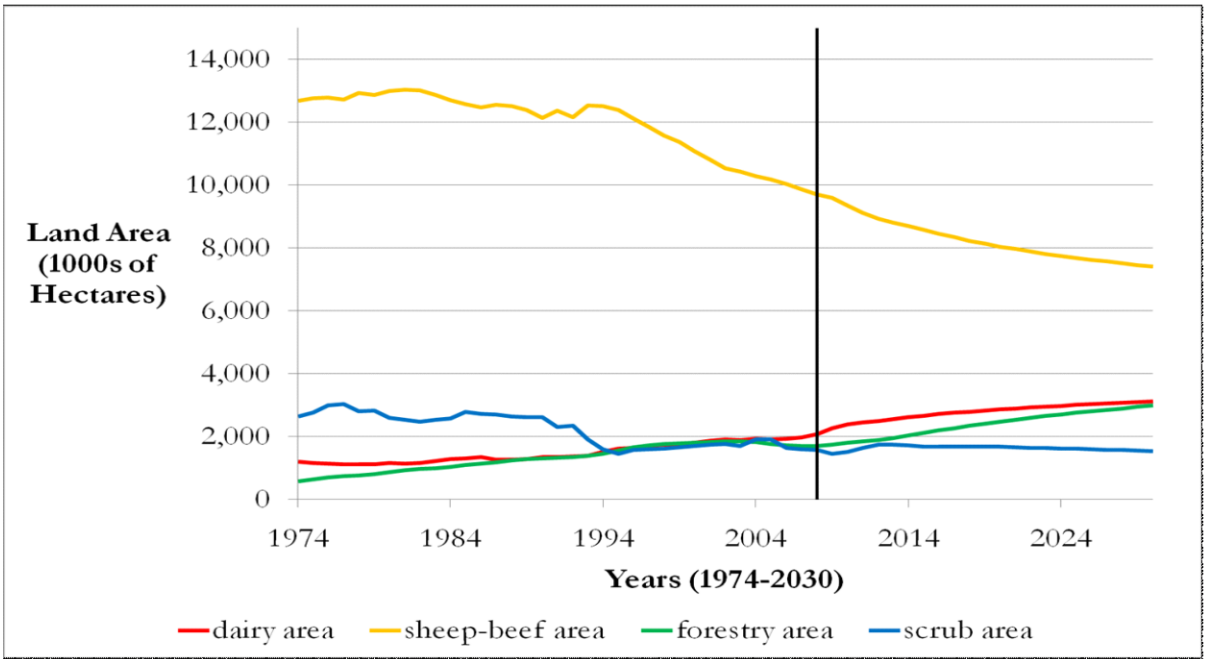


Figure 2. The evolution of national land use areas with a land use response (dashed lines)

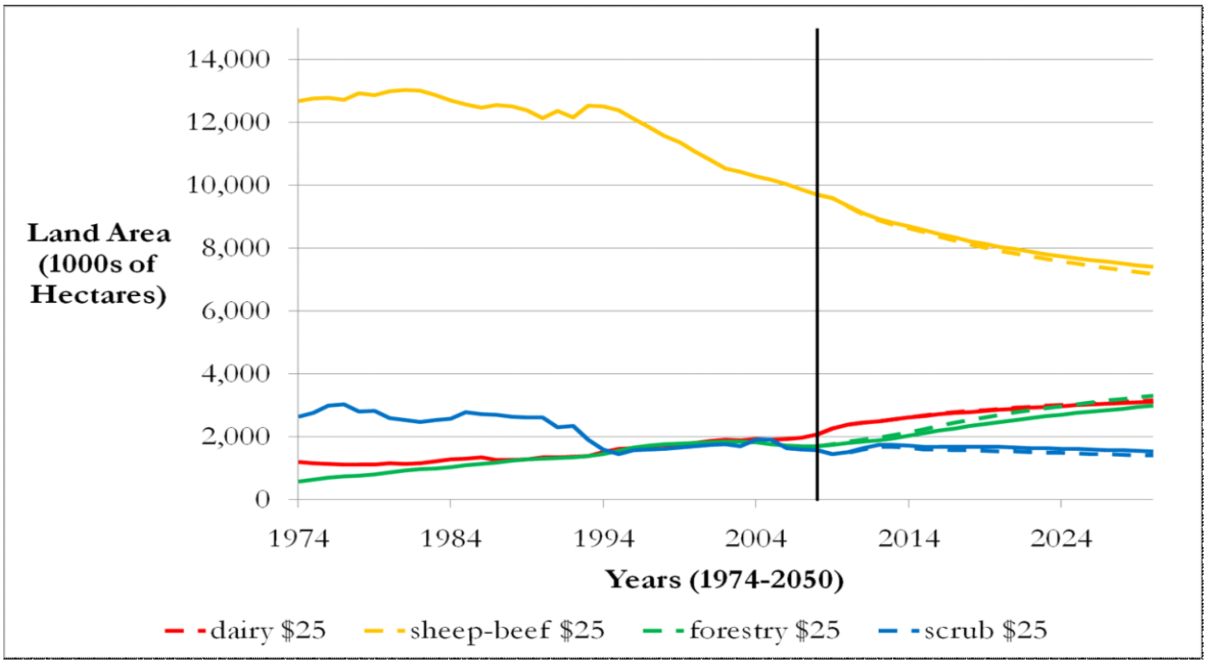
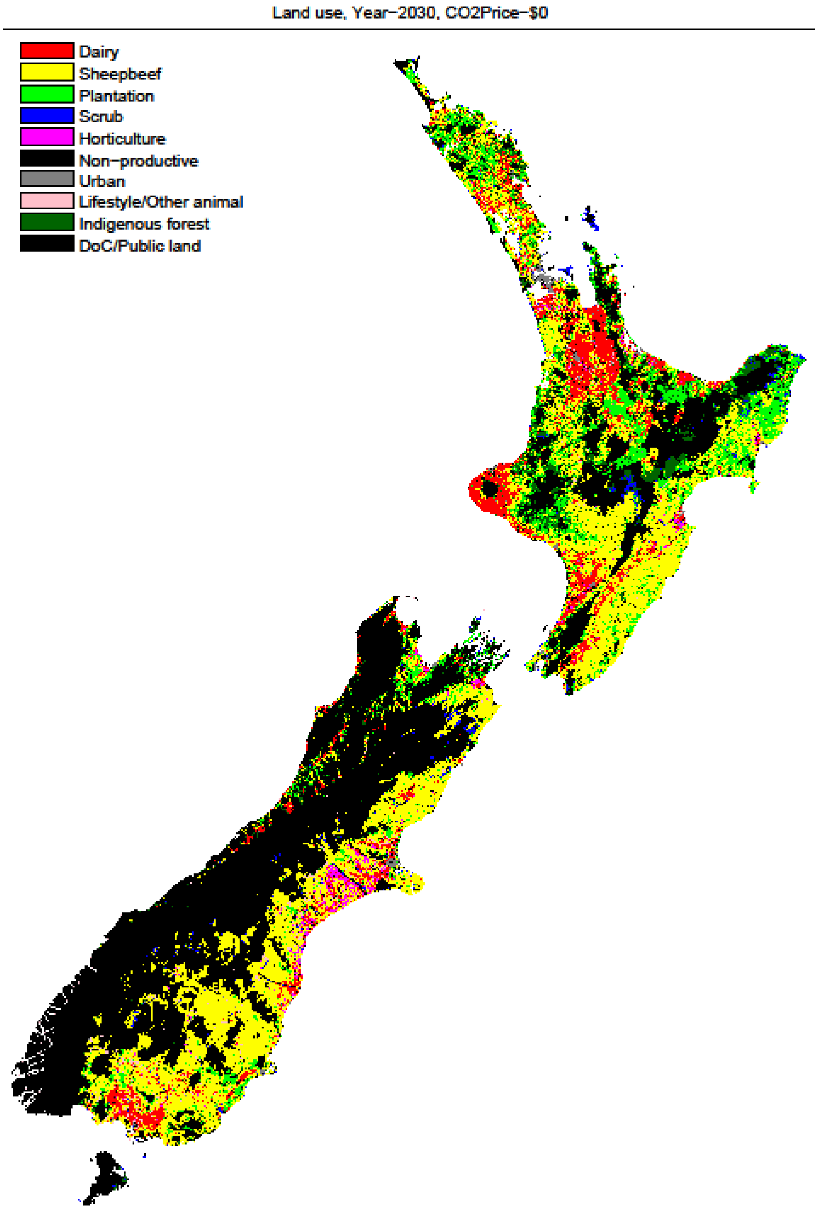


Figure 3. Geographic land use outcomes, scenario 1, year 2030



The land use simulations can be combined with the estimated trends in stocking rates and fertiliser use, geographic data on livestock carrying capacity, and information on forest age to translate the results into spatially heterogeneous carbon dioxide-equivalent greenhouse gas emissions and sequestration. These are aggregated to LMAs in tables 2 and 3.

Emission costs are directly proportional to the amount of emissions. The simplest (though technically incorrect) means of evaluating the impact of these scenarios on farmers and communities is to aggregate all emission liabilities paid and carbon credits earned. Tables 2 and 3 also show the total amount of emission liabilities and carbon revenues for each LMA. This method is used here as a first approximation. Note, however, that it leaves several important issues unaddressed. Some of these are briefly reviewed below.

For agriculture, emissions have to be fully paid each year (assuming no free allocation of emission permits), so the liabilities do represent income flows and it probably makes sense to use them to determine the direct impact on farmers. For forestry, the situation is less straightforward. Though owners of eligible forests earn carbon credits for every tonne of CO2 sequestered, these credits may not represent income flows: because the owners are also responsible for emissions associated with harvest, they may keep the accumulated credits until harvest and never sell them. Sequestration is therefore not necessarily directly proportional to income flows, and the figures shown in tables 2 and 3 likely overestimate the financial impact for forestry. The carbon management scheme owners practice depends on, among other things, their risk preferences. An alternative method of accounting for the direct impact of farmers' ability to earn credits for sequestration would be to consider it in terms of a conservative carbon management scheme in which owners only sell the credits earned during the first 10 years of a new forest. With this scheme, they will neve again incur a carbon liability – as long as their land stays in forestry use (Olssen and Kerr, 2011).

The benefits of forestry are therefore overestimated in the results below: none of the newly established forests will be harvested before the last year of simulation, so the large liabilities the harvest imposes are not recorded in the figures (but, as noted above, carbon credits earned during each year are).

Owners of land that stays in the same use across the two scenarios face exactly the same costs under both scenarios: farmers have to cover the costs of emissions from their activity and foresters receive credit for the sequestration performed by their forests. But even assuming the issue of valuing forestry credits is resolved, drawing comparisons across the scenarios is not as simple as comparing total emission liabilities and carbon revenues. This is because of land use change: it is not immediately obvious how to evaluate the effect of the policy on landowners who change their land use. For example, if a farmer were to change (across the scenarios) from dairy farming to sheep/beef farming, by definition, he could not be worse off than he would have been had he stayed in the original land use. A lower bound on the change in his welfare is therefore provided by the cost of emissions he would have had to pay had he stayed in dairy farming. Likewise, by converting to sheep/beef, the farmer cannot be better off than he originally was without the emission charge (otherwise he would not have been a dairy farmer in the first place). This provides an upper bound on his welfare change.

Evaluating conversions to forestry is further complicated by forestry's ability to earn carbon credits. It is, for example, possible that a farmer who converts from sheep/beef farming to forestry will be strictly better off in the new land use than she was in the original pastoral use without the emission charge. The bounds we can place on the welfare effect of farmers who convert to forestry are therefore even wider than those for farmers converting between pastoral uses. For these reasons, the difference between the cost of net emissions in the two scenarios provides an upper bound on the ability of farmers to mitigate through land use change. In this respect, scenario 1 represents a worst-case scenario, while scenario 2 represents a best-case scenario.

For assessing the magnitude of indirect effects and their geographic distribution, the approach taken in this paper is to calculate implied per capita costs for each LMA. The rationale behind this approach, as already noted, is that some of the indirect impacts are likely constrained to the LMA in which the direct effect occurs. The calculations assume that all of the costs of emissions and income from sequestration flow through the local community and stay within the LMA. However, it is also possible, that (at least some of) the value of forestry credits and emission liabilities will be capitalized into land values. In this case, it is the owners of the land who would be most affected, and they may often live outside the LMA. Moreover, the effect on rural land values would be a one-off decrease as opposed to the changes in annual income flows analysed in this paper – net present value analysis could be used to draw comparisons between the two cases.

With regard to establishing how owners of Maori land are affected (a potential future point of interest for this study), it is important to note that emissions on Maori freehold land are likely overestimated because stocking rates and emissions are modelled based on carrying capacity. Carrying capacity depends on land quality and it is not an actual, but rather a potential measure. Using carrying capacity to model stocking rates implicitly assumes Maori land does not differ from general land in terms of the intensity of cultivation. This is not the case in reality (MAF, 2011).

All of these are important issues that will be addressed – to the extent possible – in future versions of this paper. However, for the current preliminary analysis, I simply compare the results presented in tables 2 and 3.

Some Preliminary Results

Table 2 is based on a scenario that does not involve land use change. Some of the results in this table in effect update those of Sin et al. (2005). In addition, table 2 includes the results of modelling the effects of carbon sequestration from forestry – the credits earned are windfall gains for owners of existing forests in this case. Table 3 is derived from a scenario that also allows for land use change. Not surprisingly, the land areas used for of both types of pastoral farming systems, and agricultural emissions are lower under this scenario. Conversely, the area of plantation forestry and the amount of carbon sequestered are higher. The large differences indicate that farmers are likely to successfully mitigate some of the effects of the ETS through land use change.

Figure 4 shows the relationship between per capita costs of agricultural emissions (without the possibility of earning credits for sequestration) and median income for LMAs that have 5% or more of their workforce employed in agriculture. The relationship is slightly positive, but not strong by any means. Figures 5 and 6 depict a similar relationship, but per capita costs in these figures are calculated while accounting for credits earned for sequestration (figure 5) and both land use change and sequestration credits (figure 6). The weakly positive relationship shown in figure 4 becomes somewhat stronger in these figures (the slope of the regression line as well as R-squared increase slightly in both steps). The graphs suggest that it low-income LMAs may be able to benefit most from forestry and they are the ones who may be able to mitigate most effectively via land use change.[1]

Although the median income figures include non-agricultural jobs, the finding that low-income farmers could benefit most from carbon credits is perhaps to be expected: forestry is a viable land use alternative mainly for sheep/beef farmers who tend to be low-income compared to dairy farmers.

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[1] Results from a weighted least squares regression, where each observation is weighted by the population of the LMA, are essentially the same.

A more conspicuous change across these figures is the large decrease in the value of the intercept of the regression line: accounting for gains in forestry and for potential land use change both significantly decrease the modelled costs of the policy. The per capita costs of agricultural emissions are highest in Taihape LMA at around $2,800. With forestry credits, the highest per capita cost across the LMAs decreases to around $1,800 and it decreases further to around $1,400 when one takes land use change into account. In stark contrast to their high per capita costs plotted in figure 4, the average resident of Taihape earns nearly $2,000 in scenario 2 because sequestration exceeds emissions in the LMA (at least according to the current –preliminary– results). Large windfall gains experienced by owners of existing forests could reduce their per capita liabilities by around $2,500, and they can further benefit from land use change. Such a large difference between the scenario outcomes is not typical (as the results heavily depend on the land use profile of the TLA). Residents of Gore, for example, face substantial costs even with carbon credits and the option to change land use. The per capita impacts experienced by individual LMAs are easier to follow in figures 7, 8 and 9.

At a $25 carbon price, the aggregate (national-level) cost of agricultural emissions is approximately $1 billion in scenario 1. This is reduced to $81 million when the value of carbon credits is factored in. Finally, scenario 2 actually implies an aggregate gain of $463 million. It is important to emphasize that these results are preliminary and illustrative. The net emission and dollar figures should especially be taken with (more than) a grain of salt for the many reasons outlined above. (The qualitative results and relative magnitudes established in this early draft are not expected to change much in future revisions, however.)

Figure 4. Scenario 1: the relationship between per capita costs of agricultural emissions and median income for LMAs with at least 5% of workforce in agriculture

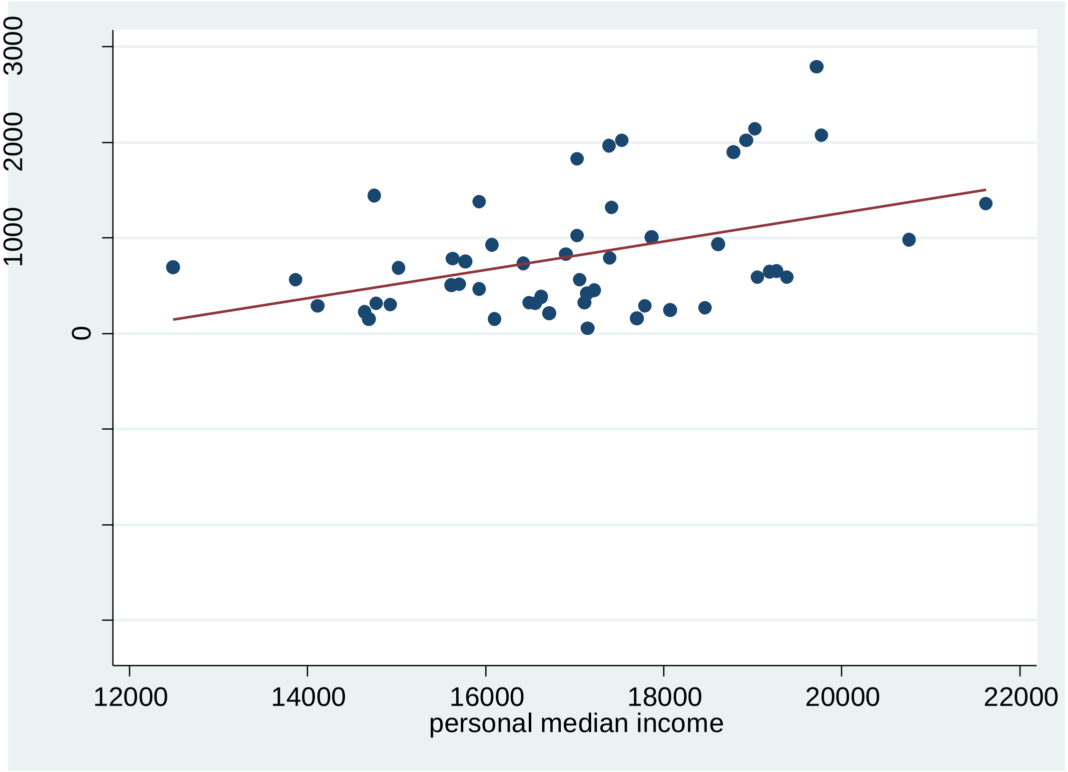

Figure 5. Scenario 1: the relationship between per capita costs (and benefits) of net emissions and median income for LMAs with at least 5% of workforce in agriculture

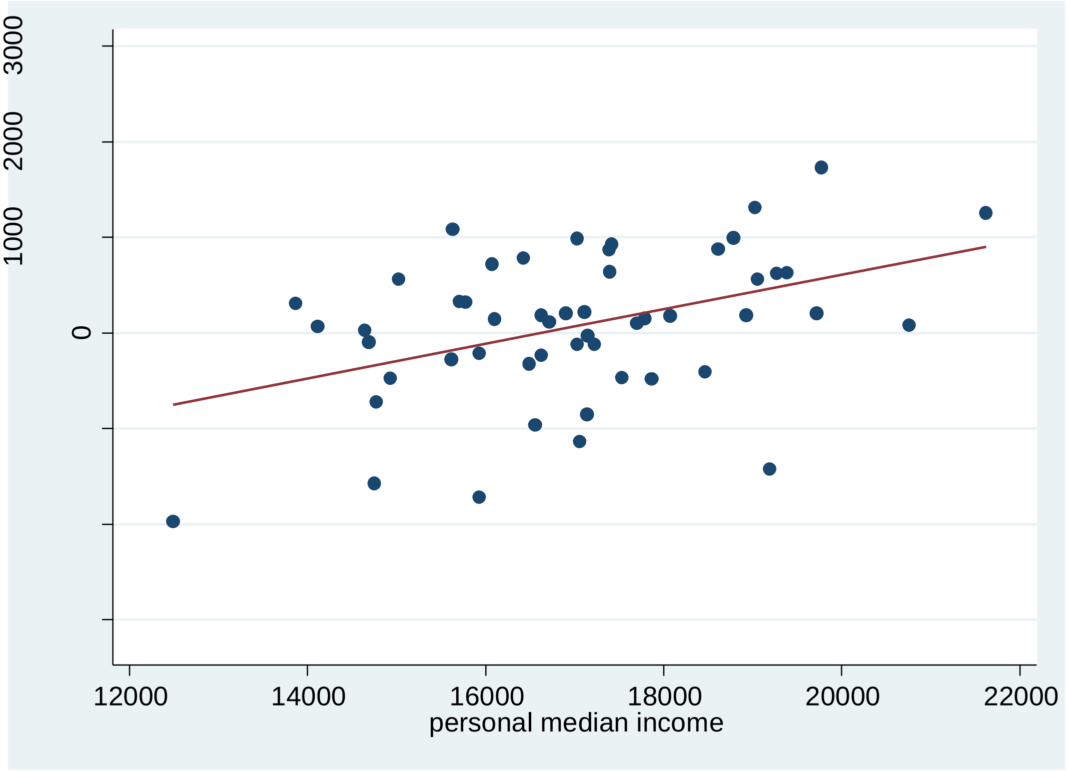

Figure 6. Scenario 2: the relationship between per capita costs (and benefits) of net emissions and median income for LMAs with at least 5% of workforce in agriculture

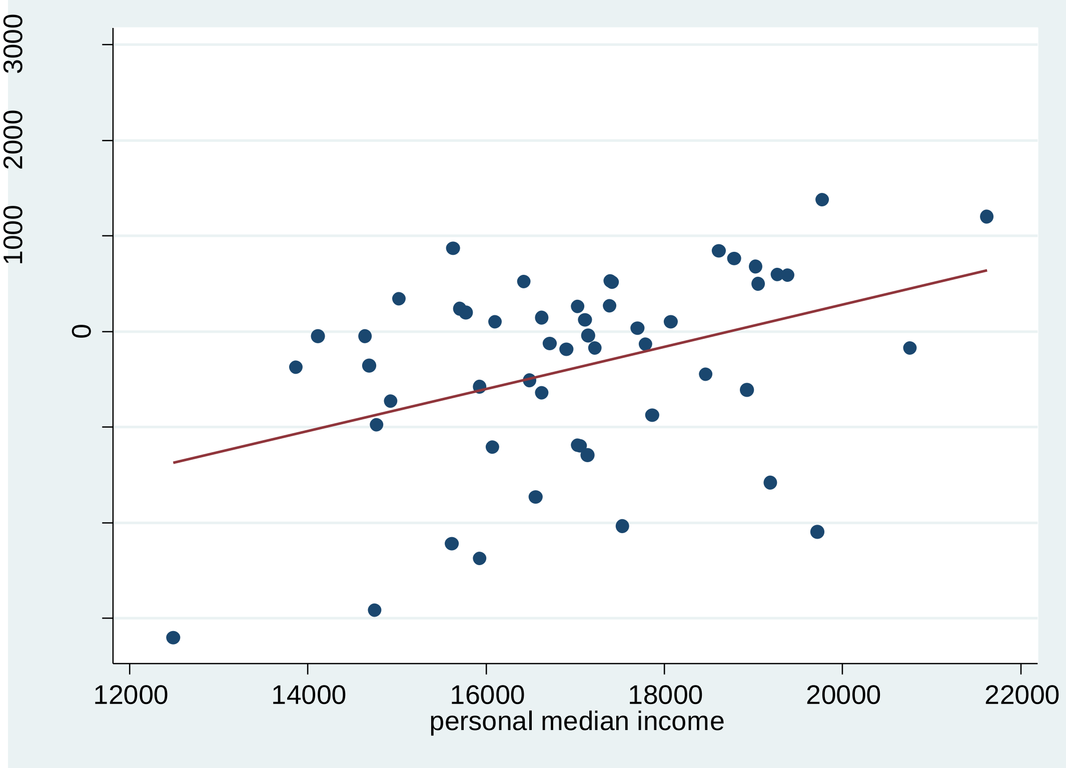

Figure 7. Scenario 1: the relationship between per capita costs of agricultural emissions and median income for LMAs with at least 5% of workforce in agriculture

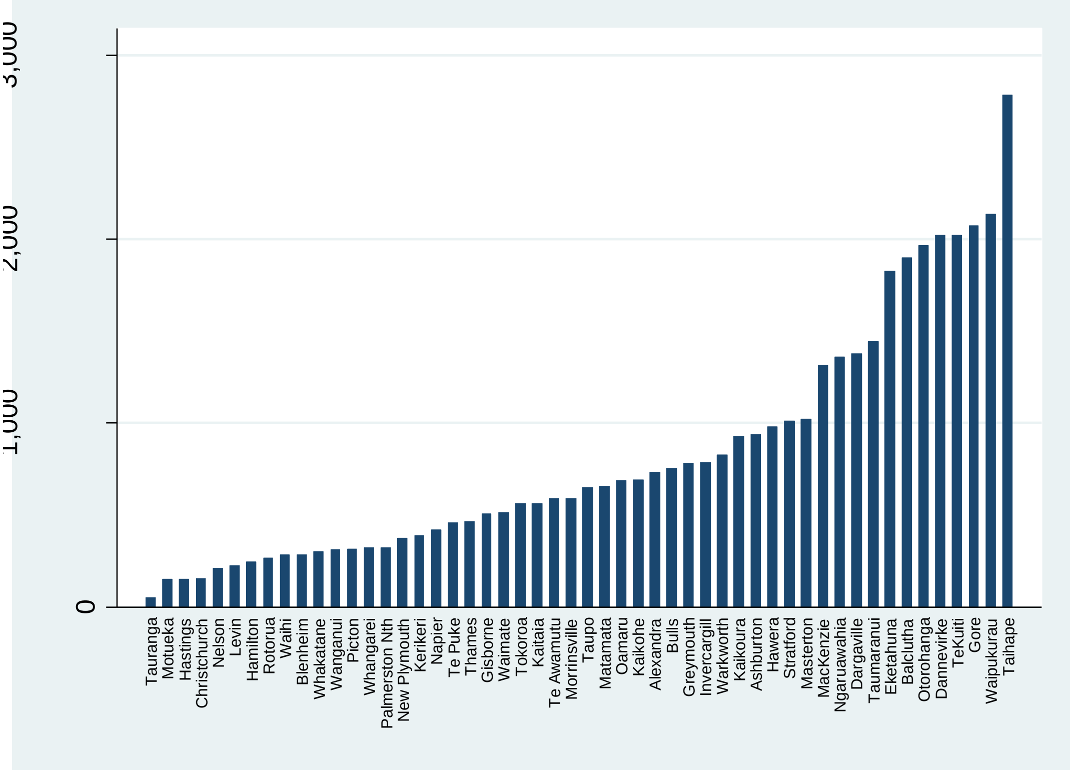

Figure 8. Scenario 1: the relationship between per capita costs (and benefits) of net emissions and median income for LMAs with at least 5% of workforce in agriculture

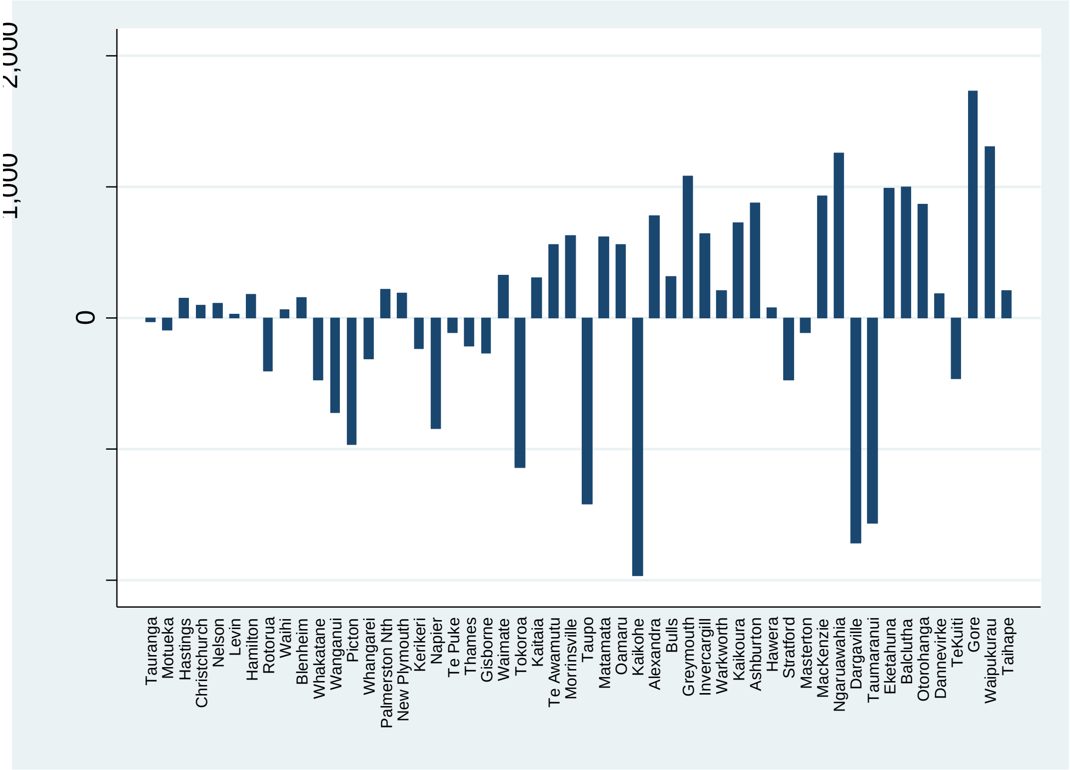

Figure 9. Scenario 2: the relationship between per capita costs (and benefits) of net emissions and median income for LMAs with at least 5% of workforce in agriculture

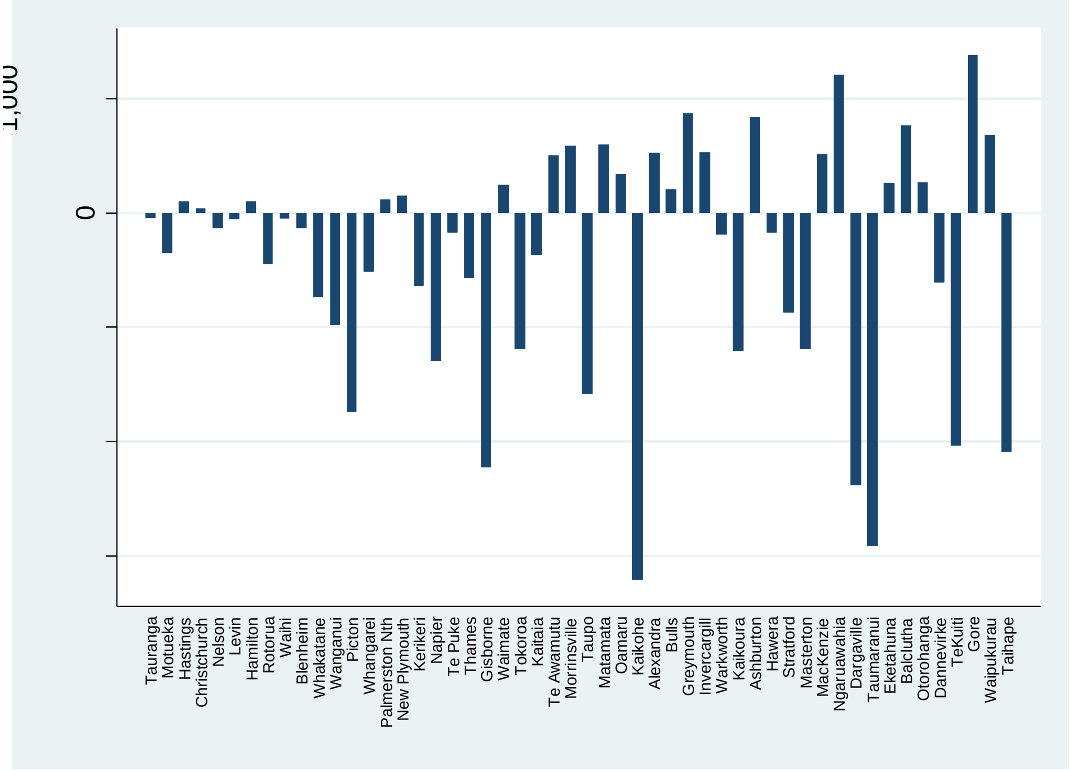

Table 1. The socio-economic characteristics of LMAs

LMA	Pop[1]	Income[2]	Empl[3]	Agri[4]	Euro[5]	Maori[6]	Pacific[7]	Asian[8]	No qual[9]	School[10]	Post[11]	Degree[12]
Kaitaia	17,634	13,866	46.18	18.79	46.60	39.79	1.19	0.82	31.11	26.36	13.91	3.12
Kerikeri	20,565	16,630	53.98	14.93	60.07	27.78	1.02	1.21	24.09	31.52	17.65	6.04
Kaikohe	13,926	12,485	41.98	21.05	28.01	57.88	1.74	0.41	31.79	24.27	13.19	3.16
Whangarei	70,539	16,490	54.12	10.75	67.81	23.13	1.07	1.50	26.91	31.21	18.65	6.02
Dargaville	9,720	15,933	57.08	29.07	69.07	23.61	1.27	0.65	33.51	30.42	15.15	3.05
Warkworth	25,734	16,899	57.48	21.25	79.72	12.35	1.06	1.13	26.96	34.24	17.57	5.48
Auckland	680,547	22,161	61.18	1.83	65.75	8.07	7.42	12.84	16.46	38.10	17.34	15.30
SthAuckland	474,768	19,670	57.95	3.28	47.26	15.46	18.67	12.32	23.92	35.70	15.46	8.43
Thames	30,495	15,928	53.65	16.14	79.09	14.36	0.88	0.95	29.92	31.46	17.17	4.79
Waihi	14,487	14,113	51.04	15.73	76.27	18.22	1.16	1.28	33.90	30.60	15.60	3.76
Ngaruawahia	10,626	21,624	64.75	37.82	82.67	11.04	0.59	1.89	31.58	34.34	15.66	3.83
Morrinsville	8,697	19,384	62.97	17.96	80.48	12.80	0.90	2.90	30.66	33.29	17.41	5.12
Matamata	10,149	19,273	61.53	24.15	80.52	14.57	0.47	1.30	32.13	32.75	15.67	4.71
Hamilton	177,570	18,075	60.68	8.00	69.81	19.34	2.00	4.91	23.80	34.50	18.51	10.92
Te Awamutu	17,502	19,057	62.35	18.78	76.14	18.58	0.65	1.08	29.32	31.62	19.27	5.33
Otorohanga	9,276	17,387	62.74	37.07	65.91	27.33	1.03	1.16	33.25	30.45	14.53	3.71
Tokoroa	24,747	17,059	56.07	18.07	55.17	30.49	8.78	1.20	34.46	28.62	15.75	3.52
TeKuiti	9,453	17,533	64.48	25.44	57.60	37.38	0.89	0.83	35.56	28.79	15.54	3.97
Taupo	30,237	19,195	59.96	11.26	64.81	26.64	1.84	1.15	25.65	33.28	18.82	5.28
Te Puke	14,901	17,222	57.62	28.74	67.20	24.02	1.27	1.85	30.46	30.70	16.88	3.89
Tauranga	111,207	17,146	55.48	8.46	78.41	14.89	0.98	1.91	25.32	34.06	19.97	6.45
Rotorua	68,016	18,466	58.83	9.04	53.97	35.39	2.23	2.47	26.17	31.27	18.26	6.59
Whakatane	45,453	14,930	52.56	14.25	49.59	43.21	1.03	0.90	30.58	29.10	17.51	4.91
Gisborne	43,983	15,616	56.11	17.62	48.66	44.03	1.47	1.04	29.72	30.35	16.82	5.19
Hastings	62,079	16,104	58.01	14.06	65.31	23.88	3.99	1.97	28.49	31.21	16.88	5.92
Napier	68,646	17,139	58.65	11.47	71.34	21.82	1.48	1.92	28.52	31.80	18.44	6.05
Waipukurau	12,825	19,026	67.03	27.45	75.79	20.73	0.94	0.51	31.09	32.85	17.85	5.03
New Plymouth	71,214	16,628	56.88	12.77	80.60	13.44	0.73	1.60	28.83	29.90	19.91	6.08
Stratford	10,980	17,866	61.67	23.18	84.78	11.26	0.30	0.71	34.64	29.21	16.18	3.80
Hawera	18,897	20,760	63.54	24.76	76.98	17.99	0.49	0.76	34.09	29.98	16.20	3.83
Taumaranui	9,060	14,754	56.74	23.45	56.79	37.09	0.79	1.26	34.42	26.84	15.65	3.74
Taihape	10,590	19,719	70.00	25.81	62.10	31.22	1.08	1.30	28.47	35.16	16.70	5.01
Wanganui	45,729	14,771	52.98	8.33	72.24	20.58	1.48	1.39	30.27	29.52	17.78	5.39
Bulls	9,513	15,769	57.33	15.23	75.56	18.89	0.79	0.69	30.46	31.55	17.09	5.39

LMA (cont'd)	Pop[1]	Income[2]	Empl[3]	Agri[4]	Euro[5]	Maori[6]	Pacific[7]	Asian[8]	No qual[9]	School[10]	Post[11]	Degree[12]
Palmerston Nth	105,711	17,108	59.48	7.91	76.60	13.36	1.96	4.17	23.72	34.90	17.60	10.79
Dannevirke	10,401	18,929	65.59	29.39	77.24	18.78	0.69	0.98	33.87	30.90	17.28	3.78
Eketahuna	7,443	17,029	62.65	28.95	79.52	16.08	0.81	0.73	34.61	30.03	16.79	4.36
Levin	31,089	14,644	50.87	12.03	71.60	20.28	2.63	2.46	33.67	29.14	16.12	4.79
Hutt Valley	127,236	21,463	62.43	1.36	69.14	15.28	6.85	5.67	24.09	35.30	18.65	9.64
Wellington	252,861	24,226	64.24	1.23	70.58	9.80	7.42	7.31	15.35	34.86	17.84	21.25
Masterton	35,898	17,030	59.77	17.47	80.75	14.00	1.54	1.14	29.43	31.33	19.03	6.47
Motueka	12,219	14,687	62.39	29.49	81.83	10.02	0.44	0.79	27.24	31.43	17.06	5.40
Nelson	78,336	16,712	61.00	12.15	87.37	6.89	0.80	1.41	25.63	32.74	20.87	7.38
Picton	7,740	16,559	56.98	16.25	79.92	12.79	0.58	0.62	29.01	30.29	18.00	4.94
Blenheim	31,827	17,790	63.82	17.02	86.57	9.13	0.85	0.93	26.86	34.18	19.81	5.64
Kaikoura	3,483	16,075	62.04	18.89	79.59	14.21	0.17	0.78	30.11	31.83	15.38	4.52
Greymouth	22,290	15,626	61.50	14.72	86.41	8.48	0.44	0.78	32.39	29.50	17.11	4.80
Christchurch	398,139	17,696	60.92	5.43	83.60	6.80	1.80	4.49	23.41	36.08	18.13	10.49
Ashburton	25,449	18,610	66.22	23.36	92.67	4.62	0.38	0.71	31.75	33.57	17.45	4.46
Waimate	49,056	15,705	58.20	13.99	90.72	5.39	0.56	1.15	31.70	31.78	17.68	4.65
MacKenzie	3,996	17,415	69.51	25.61	86.94	5.26	0.23	2.78	23.39	34.47	20.64	5.78
Oamaru	18,261	15,025	57.25	16.77	91.54	4.47	0.51	1.49	32.59	31.52	16.33	4.21
Alexandra	19,512	16,424	63.71	20.11	89.73	5.93	0.35	0.78	25.51	32.88	20.37	6.74
Queenstown	12,366	24,755	76.02	3.70	83.45	5.97	0.51	5.17	13.91	38.51	22.59	10.60
Dunedin	115,851	14,255	55.75	4.09	85.74	5.68	1.76	3.73	21.63	36.07	17.43	13.10
Balclutha	14,046	18,784	66.84	27.90	88.34	7.80	0.38	0.98	34.84	30.75	15.69	4.03
Gore	25,236	19,775	70.10	27.86	88.27	8.55	0.31	0.80	32.14	32.54	16.51	4.67
Invercargill	68,877	17,400	62.36	14.91	83.78	11.76	1.35	0.81	32.82	30.48	17.08	5.24

[1] Population
[2] Median income
[3] Employment rate
[4] Percentage of those employed in agricultural occupations
[5] Percentage European
[6] Percentage Maori
[7] Percentage Pacific Islander
[8] Percentage Asian
[9] Percentage of adults with no qualifications
[10] Percentage of adults with school qualifications only
[11] Percentage of adults with post-school qualifications
[12] Percentage of adults with degree

Table 2. Simulated ETS scenario outcomes: $25 carbon price, year 2030, no land use change

LMA	Area[1]	Area M[2]	Dairy[3]	Sheep/b[4]	Forest[5]	Scrub[6]	Ag[7]	Ag M[8]	For[9]	For M[10]	Ag cost[11]	T cost[12]
Kaitaia	2,287	149	117	635	466	37	15,881	995	-7,272	-733	562.88	305.15
Kerikeri	1,328	33	95	491	240	16	12,785	166	-20,528	-1,519	388.55	-235.33
Kaikohe	2,362	168	130	582	667	16	15,413	866	-59,398	-8,321	691.73	-1974.06
Whangarei	3,330	100	591	943	601	26	36,216	347	-72,276	-6,329	320.88	-319.50
Dargaville	1,923	54	285	741	388	21	21,441	256	-48,230	-4,832	1378.69	-1722.52
Warkworth	2,345	19	517	1,016	349	27	34,119	220	-25,523	-919	828.65	208.79
Auckland	2,028	10	159	524	145	179	14,074	20	-5,676	0	12.93	7.71
SthAuckland	2,918	30	681	1,055	206	41	40,262	268	-12,892	-2,078	53.00	36.03
Thames	2,780	37	515	324	368	54	22,682	131	-33,177	-1,423	464.87	-215.09
Waihi	622	15	116	157	59	1	6,593	123	-5,140	-923	284.42	62.70
Ngaruawahia	969	9	649	70	16	0	23,101	205	-1,756	-94	1358.74	1255.45
Morrinsville	328	3	205	78	3	0	8,206	44	557	-175	589.74	629.80
Matamata	459	7	285	53	6	0	10,635	113	-602	-194	654.94	617.86
Hamilton	4,011	91	1,365	1,422	270	31	69,588	524	-18,590	-6,125	244.93	179.50
Te Awamutu	668	8	405	154	12	0	16,501	186	-854	-116	589.26	558.76
Otorohanga	1,992	79	479	654	184	1	29,157	613	-16,290	-5,067	1964.55	866.96
Tokoroa	1,819	24	471	274	735	0	22,283	303	-67,490	-1,331	562.78	-1141.72
TeKuiti	3,532	160	229	1,321	563	30	30,576	773	-37,644	-9,585	2021.56	-467.36
Taupo	6,953	534	357	1,361	1,152	51	31,449	1,742	-100,432	-38,546	650.06	-1425.88
Te Puke	805	25	248	127	131	0	10,883	532	-13,759	-747	456.48	-120.61
Tauranga	1,223	50	144	233	134	2	9,270	542	-14,777	-3,423	52.10	-30.95
Rotorua	4,655	276	528	628	760	12	29,087	1,215	-73,490	-22,706	267.28	-408.02
Whakatane	5,493	409	437	404	795	66	21,872	1,937	-56,754	-14,425	300.75	-479.65
Gisborne	8,344	1,042	70	2,543	2,986	376	35,548	2,895	-54,747	7,032	505.13	-272.83
Hastings	1,619	49	85	819	91	35	15,058	364	-380	-796	151.61	147.79
Napier	7,826	388	160	2,783	1,665	70	46,209	1,053	-139,519	-29,295	420.72	-849.56
Waipukurau	3,323	70	180	2,543	193	9	43,858	406	-17,013	-4,594	2137.34	1308.27
New Plymouth	2,847	32	1,100	354	210	0	42,795	688	-21,355	-566	375.58	188.16
Stratford	2,171	6	323	504	227	0	17,751	30	-26,209	-360	1010.43	-481.43
Hawera	2,154	22	715	348	264	0	29,605	528	-27,283	-400	979.14	76.79
Taumaranui	4,018	98	55	1,342	660	2	20,923	314	-43,744	-7,983	1443.36	-1574.30
Taihape	6,559	435	80	3,213	473	255	47,192	1,665	-43,698	-9,273	2785.16	206.22
Wanganui	3,136	58	216	1,039	751	21	22,705	349	-75,597	-2,635	310.32	-722.90
Bulls	630	4	221	259	51	0	11,454	73	-6,622	-98	752.54	317.48

LMA (cont'd)	Area[1]	Area M[2]	Dairy[3]	Sheep/b[4]	Forest[5]	Scrub[6]	Ag[7]	Ag M[8]	For[9]	For M[10]	Ag cost[11]	T cost[12]
Palmerston Nth	3,255	26	858	1,617	145	3	54,487	389	-17,451	-331	322.15	218.97
Dannevirke	2,593	14	262	1,851	254	1	33,620	235	-30,518	-532	2020.24	186.43
Eketahuna	1,693	4	221	1,158	78	0	21,734	40	-9,969	-249	1825.07	987.96
Levin	1,218	34	247	216	84	9	11,209	430	-9,834	-977	225.35	27.66
Hutt Valley	901	4	12	131	74	15	1,956	5	-7,524	-177	9.61	-27.35
Wellington	750	2	15	243	119	34	3,403	0	-13,375	-159	8.41	-24.65
Masterton	5,997	37	439	3,315	663	50	58,791	273	-65,647	-1,656	1023.58	-119.36
Motueka	716	0	37	165	144	2	2,938	0	-4,831	0	150.26	-96.85
Nelson	14,062	0	475	1,022	826	24	26,344	0	-12,451	0	210.18	110.84
Picton	2,598	1	78	118	426	92	3,908	0	-15,881	-5	315.55	-966.86
Blenheim	7,860	0	91	2,255	349	197	14,486	0	-6,577	0	284.47	155.31
Kaikoura	2,041	0	36	517	55	158	5,176	0	-1,140	0	928.71	724.11
Greymouth	13,163	1	629	641	307	3	27,873	0	10,660	-3	781.55	1080.45
Christchurch	18,900	1	1,093	7,499	531	194	99,653	2	-36,993	-26	156.44	98.37
Ashburton	6,185	0	539	1,795	39	65	38,162	0	-2,506	0	937.23	875.69
Waimate	6,305	0	423	3,023	208	83	40,282	5	-14,721	0	513.22	325.66
MacKenzie	7,481	0	8	1,282	37	21	8,398	0	-2,444	0	1313.56	931.28
Oamaru	6,061	0	248	2,278	82	60	20,110	0	-3,714	0	688.27	561.15
Alexandra	19,931	0	31	5,707	62	106	22,937	0	1,386	0	734.72	779.11
Queenstown	4,777	0	2	580	16	87	2,014	0	-1,090	0	101.77	46.68
Dunedin	4,362	0	138	3,027	265	16	24,672	0	-28,179	0	133.10	-18.92
Balclutha	4,020	0	300	2,352	467	42	42,673	0	-20,262	0	1898.80	997.21
Gore	24,906	0	420	5,376	473	39	83,663	0	-13,697	0	2072.01	1732.79
Invercargill	9,069	10	1,567	2,339	432	80	86,675	0	-15,852	0	786.50	642.66
Total	266,294	4,621	20,374	77,495	21,953	2,754	1,600,338	21,866	-1,470,765	-182,690	267.64	21.67

[1] Area in square km
[2] Area of Maori land in square km
[3] Dairy area, square km
[4] Sheep or beef area, square km
[5] Forestry area, square km
[6] Scrub area, square km
[7] Agricultural emissions, tonnes of carbon dioxide equivalent (CO2e)
[8] Agricultural emissions (tonnes CO2e) on Maori land
[9] Forestry emissions (tonnes CO2e)
[10] Forestry emissions (tonnes CO2e) on Maori land
[11] Per capita cost of agricultural emissions
[12] Per capita cost of total emissions

Table 3. Simulated ETS scenario outcomes: $25 carbon price, year 2030, with land use change

LMA	Area[1]	Area M[2]	Dairy[3]	Sheep/b[4]	Forest[5]	Scrub[6]	Ag[7]	Ag M[8]	For[9]	For M[10]	Ag cost[11]	T cost[12]
Kaitaia	2,287	149	109	562	569	15	14,842	911	-25,372	-5,025	526.05	-373.19
Kerikeri	1,328	33	95	428	310	8	11,890	88	-32,991	-3,885	361.37	-641.28
Kaikohe	2,362	168	124	449	824	0	13,333	733	-84,744	-16,086	598.39	-3204.90
Whangarei	3,330	100	589	839	723	11	34,899	287	-92,608	-10,552	309.22	-511.31
Dargaville	1,923	54	266	699	456	14	20,554	240	-57,545	-5,383	1321.61	-2378.56
Warkworth	2,345	19	501	909	473	27	32,459	164	-40,307	-1,693	788.33	-190.60
Auckland	2,028	10	105	501	222	178	12,596	20	-14,802	0	11.57	-2.03
SthAuckland	2,918	30	514	1,099	329	41	36,354	249	-26,765	-2,402	47.86	12.62
Thames	2,780	37	431	318	462	49	20,447	125	-48,518	-2,612	419.06	-575.31
Waihi	622	15	102	158	73	1	6,178	123	-7,229	-1,037	266.53	-45.32
Ngaruawahia	969	9	638	77	21	0	22,873	205	-2,378	-100	1345.36	1205.47
Morrinsville	328	3	195	87	3	0	8,065	44	78	-197	579.60	585.23
Matamata	459	7	278	59	8	0	10,518	108	-882	-214	647.70	593.38
Hamilton	4,011	91	1,168	1,465	412	43	64,739	423	-37,173	-8,090	227.87	97.03
Te Awamutu	668	8	381	169	21	0	16,076	186	-2,065	-130	574.09	500.35
Otorohanga	1,992	79	471	597	242	8	27,960	454	-24,016	-5,994	1883.92	265.75
Tokoroa	1,819	24	454	276	742	7	21,863	277	-69,230	-1,846	552.18	-1196.28
TeKuiti	3,532	160	182	1,232	702	27	27,824	667	-58,614	-12,886	1839.61	-2035.76
Taupo	6,953	534	338	1,331	1,233	18	30,766	1,340	-107,232	-42,456	635.94	-1580.55
Te Puke	805	25	226	140	138	3	10,487	532	-14,711	-621	439.87	-177.16
Tauranga	1,223	50	110	246	142	15	8,525	383	-15,771	-3,311	47.91	-40.73
Rotorua	4,655	276	485	619	803	21	27,795	1,082	-76,957	-24,731	255.41	-451.75
Whakatane	5,493	409	362	407	895	37	19,854	1,456	-73,191	-20,566	273.00	-733.42
Gisborne	8,344	1,042	39	2,297	3,627	13	32,582	2,679	-189,032	-61,598	462.99	-2223.16
Hastings	1,619	49	42	839	129	19	14,222	332	-4,748	-1,753	143.19	95.39
Napier	7,826	388	86	2,644	1,912	36	42,770	972	-185,087	-40,841	389.41	-1295.75
Waipukurau	3,323	70	118	2,513	266	28	42,026	351	-28,036	-6,497	2048.03	681.77
New Plymouth	2,847	32	1,020	376	230	38	40,996	628	-24,146	-806	359.80	147.89
Stratford	2,171	6	322	456	276	0	17,225	30	-32,597	-429	980.46	-874.98
Hawera	2,154	22	667	349	296	15	28,596	528	-33,988	-402	945.80	-178.31
Taumaranui	4,018	98	54	1,234	770	1	19,637	310	-61,907	-8,789	1354.62	-2915.97
Taihape	6,559	435	49	3,094	874	4	45,681	1,540	-81,204	-26,321	2695.98	-2096.48
Wanganui	3,136	58	160	991	864	12	21,120	294	-92,569	-6,102	288.66	-976.52
Bulls	630	4	84	390	51	5	9,692	64	-6,627	-102	636.74	201.35

LMA (cont'd)	Area[1]	Area M[2]	Dairy[3]	Sheep/b[4]	Forest[5]	Scrub[6]	Ag[7]	Ag M[8]	For[9]	For M[10]	Ag cost[11]	T cost[12]
Palmerston Nth	3,255	26	462	1,880	263	19	48,958	385	-29,127	-512	289.46	117.25
Dannevirke	2,593	14	260	1,748	359	1	32,525	230	-42,690	-750	1954.42	-610.84
Eketahuna	1,693	4	219	1,081	156	2	20,983	37	-17,869	-322	1761.99	261.50
Levin	1,218	34	171	272	104	9	10,121	423	-12,646	-1,112	203.48	-50.75
Hutt Valley	901	4	6	55	167	4	1,089	5	-17,067	-309	5.35	-78.48
Wellington	750	2	5	176	202	29	2,433	0	-21,382	-104	6.01	-46.84
Masterton	5,997	37	287	3,085	1,077	17	52,636	190	-121,087	-2,574	916.41	-1191.77
Motueka	716	0	20	130	196	3	2,310	0	-9,250	0	118.15	-354.98
Nelson	14,062	0	384	845	1,084	33	22,529	0	-39,087	0	179.75	-132.10
Picton	2,598	1	69	104	489	52	3,603	0	-25,114	-50	290.96	-1736.98
Blenheim	7,860	0	40	2,098	754	0	13,093	0	-19,906	0	257.11	-133.80
Kaikoura	2,041	0	28	408	331	0	4,408	0	-11,162	0	790.93	-1212.01
Greymouth	13,163	1	535	568	477	0	25,368	0	5,557	-39	711.31	867.12
Christchurch	18,900	1	626	7,485	1,206	0	88,769	0	-66,536	-26	139.35	34.90
Ashburton	6,185	0	528	1,765	145	0	37,789	0	-3,662	0	928.07	838.14
Waimate	6,305	0	320	3,060	357	0	38,192	5	-19,171	0	486.58	242.33
MacKenzie	7,481	0	8	1,230	110	0	8,341	0	-5,072	0	1304.63	511.40
Oamaru	6,061	0	219	2,194	255	0	19,388	0	-9,521	0	663.58	337.70
Alexandra	19,931	0	31	5,583	291	0	22,727	0	-6,467	0	727.97	520.82
Queenstown	4,777	0	2	499	185	0	1,878	0	-4,384	0	94.90	-126.66
Dunedin	4,362	0	112	2,967	366	0	23,891	0	-39,743	0	128.89	-85.52
Balclutha	4,020	0	262	2,380	519	0	41,891	0	-24,736	0	1864.03	763.37
Gore	24,906	0	367	5,273	668	0	81,649	0	-25,976	0	2022.14	1378.82
Invercargill	9,069	10	837	2,949	630	1	76,680	0	-18,515	-30	695.80	527.80
Total	266,294	4,621	16,558	75,677	29,480	862	1,496,696	19,100	-2,237,570	-329,281	250.31	-123.90

[1] Area in square km
[2] Area of Maori land in square km
[3] Dairy area, square km
[4] Sheep or beef area, square km
[5] Forestry area, square km
[6] Scrub area, square km
[7] Agricultural emissions, tonnes of carbon dioxide equivalent (CO2e)
[8] Agricultural emissions (tonnes CO2e) on Maori land
[9] Forestry emissions (tonnes CO2e)
[10] Forestry emissions (tonnes CO2e) on Maori land
[11] Per capita cost of agricultural emissions
[12] Per capita cost of total emissions

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