Greenhouse gas emissions charges and credits on agricultural land: what can a model tell us?

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Abstract

Using the simulation model Land Use in Rural New Zealand version 1 - climate (LURNZv1-climate), we simulate the effects of an agricultural land-use emissions charge and a reward for native forest and scrub regeneration. Our results are preliminary and at this stage should be considered illustrative. We find that, on its own, an agricultural emissions charge based on solely on land use would be disruptive and may not be very effective in reducing emissions. In addition, we find that including an additional policy that rewards regenerating forest and scrub without a similar reward for plantation forestry might negatively impact on plantation forestry, increasing emissions growth in the short-run. We are currently developing a second version of LURNZ-climate, which will be more robust and thus lend more weight to our future results.

JEL classification

Q24, Q15, Q18, R14, Q54, Q58

Keywords

Climate change, land use, methane, nitrous oxide, dairy, sheep, beef, Government policy

1 Introduction

Policies designed to mitigate greenhouse gas emissions through the Kyoto Protocol have the potential to create political firestorms. In 2003, the government proposed the ill-fated "fart" tax – this small research levy ignited a damaging political firestorm despite representing a charge of only 25 cents per tonne carbon dioxide equivalent. This levy pales in comparison to the price of European Union Allowances, which have exceeded NZ$50 per tonne in March and April 2006 before falling back dramatically. Was the outrage all hot air? We use the simulation model Land Use in Rural New Zealand – climate (LURNZ–climate) to explore the impacts of high emissions charges (NZ$50 per tonne) on productive land uses including dairying, sheep and beef agriculture, and forestry. The results demonstrate the potential connections between greenhouse gas mitigation policies across sectors. We examine the large economic and potentially quite small emissions impacts that could result from exposing agriculture to the international emissions price. We also examine the land use and emissions implications of proposed policies that would give landowners emissions credits for regenerating indigenous forest and scrub. In the absence of a parallel policy for production forestry, the results are surprising and potentially disappointing for proponents of biodiversity.

2 About LURNZ-climate

To examine the impacts of devolving Kyoto credits and liabilities for emissions and sinks to land owners, economists at Motu Economic and Public Policy Research, and scientists at institutes including Landcare Research, AgResearch, Scion/Ensis (Forest Research), and NIWA have combined their efforts to develop LURNZ-climate. Based on economics and natural science, LURNZ-climate is a computer model that simulates the effect of climate change related government policies on rural land use in New Zealand. LURNZ-climate predicts land-use change at a fine spatial scale over the whole country, producing dynamic paths of rural land-use change and maps of rural land use across New Zealand. In addition, LURNZ-climate calculates the greenhouse gas implications of land-use change. With the development of LURNZ-climate, New Zealand now has the capacity to empirically investigate the potential impacts of policies designed to alter land-use decisions, including policies such as a charge to farmers in proportion to the amount of methane and nitrous oxide their livestock emit and a reward for regenerating indigenous forest and scrub.

The first version of LURNZ-climate, LURNZv1-climate, is now operational. LURNZv1-climate models land-use change on 25ha grid-cells in a grid covering New Zealand for four major rural land uses: dairy farming, sheep/beef farming, plantation forestry, and regenerating indigenous forest and scrub. In addition, LURNZv1-climate calculates the emissions impacts of these land uses for the three most important land use related greenhouse gases: methane, nitrous oxide, and carbon dioxide.

We built the LURNZv1-climate database by collecting and enhancing existing datasets describing land characteristics, including land cover, land use, economics, governance, geophysical variables and greenhouse gas data. The database also includes data on greenhouse gas emissions and removals related to each land use. The land use and cover variables come from the Ministry for the Environment's Land Cover Database (LCDB), which is based on satellite measurements of land cover, and agricultural surveys and censuses. The economic variables include commodity prices, yields, revenues and expenditures, costs of land use transitions, amenities, and land values. The governance variables include maps of conservation and Maori owned land. The geophysical variables include existing maps such as land-use capability, soil, climate, slope, and land-use-specific productivity indices developed specifically for this project. The greenhouse gas data include methane and nitrous oxide emissions for dairy, sheep, and beef livestock, and fertiliser, and measures of removal of carbon dioxide from the atmosphere by plantation forestry and regenerating indigenous forest and scrub. They come from the data collected for the 2002 National Inventory report (Brown and Plume, 2004) with additional information from Landcare Research (Hendy and Kerr, 2005).

The land use component of the model is based upon a micro-economic theoretical model that assumes landowners choose the land use that will give them the highest economic return, depending on potential returns, conversion costs, and relative uncertainties associated with the different land uses. To develop LURNZv1, we derived hypotheses from this theory and then statistically tested them against actual data. In doing this, we estimated the relationship between national level land use and prices, interest rates, area of non-rural land, and the average trend in all unobserved factors such as costs and relative uncertainties, using 29 years of historical data; this process is explained in more detail in Kerr and Hendy (2006). LURNZv1 uses these estimated relationships to predict short run land-use adjustment to economic shocks and long run equilibrium land use at the national level. LURNZv1 then uses spatial algorithms to map predicted changes across New Zealand, based on the assumption that, in response to an economic shock, it is marginal land that will change land use first. LURNZv1 is explained in more detail in Hendy, Kerr, and Baisden (2006).

The greenhouse gas module in LURNZv1-climate includes functions that project land-use related greenhouse gas emissions per unit of economic activity. The functions are simple; are based on readily available data and strong science; are consistent with the national inventory in 2002; evolve so that implied net emissions approximately match past inventory totals (1990-2002); and can be linked easily to a variety of models so they can be used in simulations. Combined with simple projections of the intensity of land-use for each land-use type, the greenhouse gas module calculates emissions associated with one hectare of each land use. This is explained in more detail in Hendy and Kerr (2005) and Hendy and Kerr (2006). Finally, combining the predictions of land-use change with the projections of land-use emissions per hectare, LURNZv1-climate calculates the emissions implications of land-use change.

For the remainder of this article we discuss results produced from LURNZv1-climate. Given that the relationships driving the land-use responses in LURNZv1-climate are still under development, the underlying mechanisms of the model will be examined further before results can be considered robust in terms of timing or magnitude. Thus, the results presented should be taken as qualitative illustrations of issues arising from the modelled policies.

3 Charging farmers for their land-use emissions

As a signatory to the Kyoto Protocol, the government is obliged to reduce New Zealand's annual emissions to the 1990 level during the 2008-2012 period or buy assigned amount units on the international market to make up the difference. Although agricultural emissions have been rising at a much slower rate than New Zealand's overall emissions, in which growth is driven largely driven by the transport sector, agricultural land use emissions, caused mostly by methane produced by grazing animals and nitrous oxide derived from animal excrement, constitute approximately half of New Zealand's overall greenhouse gas emissions (Brown and Plume, 2004). Therefore, reducing land-use emissions could significantly help New Zealand to meet its target and contribute efficiently to controlling greenhouse gases. A potential policy to help encourage emission reductions would be to charge farmers in proportion to the amount of emissions that their animal production produces. This would lead farmers to reduce area in livestock and particularly in dairy, reduce stocking rates and, if possible, change farm management to reduce emissions per animal. Current methane and nitrous oxide monitoring technology makes accurate animal or farm-scale monitoring of emissions impossible. The proposed policy related payments only to livestock numbers, which can be monitored. Because of current limitations in LURNZ, we model an even simpler policy where the government simply charges farmers in proportion to their land area in each land use, and assumes that each farm emits an average amount per hectare. This is a less flexible policy because farmers cannot change their stocking rates in response to the charge. We therefore underestimate the size of the likely response to a charge based on livestock numbers.

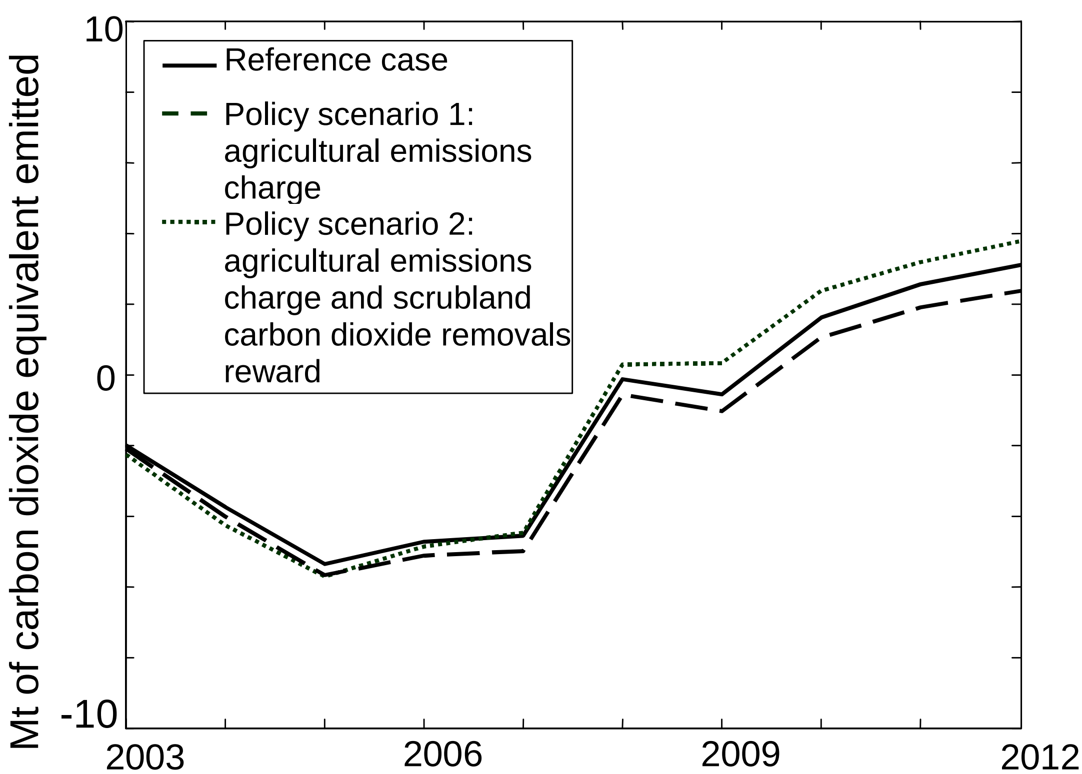
If dairy farmers were charged \$50 for every tonne of carbon dioxide equivalent emitted in 2002, based on average values, their income would decrease 60 cents for each kilogram of milk solids that they produced. On average in 2002, farmers received \$5.31 per kilogram of milk solids, so this charge would have equated to an 11% reduction in revenue. If sheep/beef farmers were charged the same amount per tonne of carbon dioxide equivalent, they would pay 85 cents for every kilogram of combined meat and wool, equivalent to a 22% reduction in revenue. The impact of these revenue reductions can be measured against net profits, which were $126,469 for dairy farms and $113,303 for sheep/beef farms when averaged over the last five years (New Zealand. Ministry of Agriculture and Forestry, 2001-2005a and 2001-2005b). This charge would have reduced net profits by $48,693 for the average dairy farm and $38,116 for the average sheep/beef farm. These impacts would directly lower land values and hence farmer wealth.

The charge would also affect people other than farmers, as the indirect effects would spread out through the economy. Farmers, who would have to pay the huge cost, would likely reduce their spending. This would negatively affect their communities, in particular including laying off farm workers or lowering their wages. Farm workers in return would reduce their own expenditure. Thus, the effects of the charge would flow on through the economy. Sin et al (2004) found that the areas likely to be hardest hit by an emissions charge would be Gore and MacKenzie in the South Island, and Taihape, Waipukurau, Te Kuiti and Dannevirke in the North Island. The effect on the economy as a whole may not be large after an initial period of adjustment if the revenue from the charge were recycled into other tax cuts, but the transfers of income between people and the dislocation in some communities would be significant.

In response to such a policy, some marginal land is likely to change to a lower emitting land use. If, for example, sheep/beef farming on a parcel of marginal land is no longer profitable, the land is likely to enter plantation forestry or a state, which we refer to as regenerating forest and scrub, in which no economic activity is discernable. It is also likely that some land will move from dairy to sheep/beef (or not convert to dairy as soon – if dairy prices and conversions continue to be high). For example, facing such a charge, farms considering converting to dairy would find that the difference between their current returns in sheep/beef farming and the returns they could potentially earn in dairy would be reduced. This is because dairy farming has higher emissions per hectare than sheep/beef farming so they face a higher charge. For some farms on the margin for conversion to dairy, this effect might be large enough to make sheep/beef more profitable than dairy, and so these farms might choose not to convert and thereby reduce New Zealand's total emissions. In all cases, the resulting land-use changes will result in lower emitting land use, achieving the goal of the policy. However, the costs to enterprises and rural economies may be sufficiently large that the policy is not currently justified, relative to other policies that would induce emissions reductions in other sectors.

To examine the impact of a NZ$50 per tonne of carbon dioxide equivalent charge on New Zealand agriculture, we ask, how big would the corresponding emissions reductions be? To answer this, we first need to know what would have happened if no policy was introduced. To tell us this, we simulate a reference case scenario. The reference case gives us a line against which we can measure the effectiveness of the policy, allowing us to observe the magnitude of the policy effect and discern whether the policy is achieving its intended result.

Figure 1 Emissions under different policy scenarios



For our reference case, we project changes in land use and emissions from 2003 to 2012, using Ministry of Agriculture and Forestry forecasts of commodity prices and assuming that both the interest rate and the area of non-rural land are constant. Based on this scenario, LURNZv1 projects that by 2012 dairy area will expand by 1.2% (18,000ha), sheep/beef area will contract by 2.8% (199,000ha), plantation forestry will expand by 17.4% (273,000ha), and regenerating forest and scrub will contract by 5.5% (92,000ha) compared to 2002. The solid line in the figure shows the corresponding agricultural emissions for the reference case over the period. The emissions are calculated as total methane and nitrous oxide emissions from dairy, sheep, and beef livestock, and fertiliser use, net of carbon dioxide removed by plantation forests and regenerating indigenous forest and scrub.

To find out how much the charge would reduce emissions, we model the charge as a reduction in the commodity price that farmers receive, assuming that farmers will respond to the charge in the same way as a commodity price shock. From 2003 onwards, we reduce the commodity prices relative to those we used in the reference case by the equivalent of 60 cents for milk solids and 85 cents for meat and wool; these reductions correspond to a charge of $50 per tonne of carbon dioxide equivalent. We expect that, when compared to the reference case, dairy would expand less, sheep/beef would contract more, plantation forests would expand more, and regenerating forest and scrub would contract less. As a result, we expect that the rise in emissions would be reduced and indeed this is the case. The dashed line in the figure shows net emissions associated with this scenario.

We find that dairy area contracts by 1% with the policy, whereas in the reference case it expanded by 1.2%. Sheep/beef area contracts by 0.3 percentage points more than in the reference case, plantation forestry stays about the same, and regenerating forest and scrub contracts by 3.8 percentage points less than in the reference case. The land-use change caused by the policy reduces the annual growth rate in emissions during 2003 – 2012 from about 0.5 million tonnes of carbon dioxide equivalent per year in the reference case to about 0.4 million tonnes of carbon dioxide equivalent per year.

The lower emissions rate from a charge based on land use equates to a 6% relative reduction in emissions over the first commitment period. This is a small reduction for a large emissions price. The result therefore suggests that an emissions tax levied on agriculture will result in relatively small reductions in emissions, relative to reductions in the profitability of farming that are likely to flow through the economy. Thus, a policy levying an emissions charge on agriculture based on emissions per hectare remains a relatively poor policy option, presuming that significant impacts on land values rural workers and rural communities cannot be addressed. It is possible however, that the current model underestimates the magnitude of change that could be achieved through slightly more targeted policies. A more sophisticated policy, such as a policy where the government monitored livestock numbers and fertiliser use within each land use, could give more dimensions along which farmers could reduce their emissions.

4 Rewarding farmers for regeneration of marginal land

The Government might be able to induce a greater reduction in emissions and at the same time reduce the impact on farmers, if the government rewarded the regeneration of indigenous forest and scrub on marginal land. The Government has developed a policy called the Permanent Forest Sinks Initiative (PFSI) that would provide such an alternative. In addition to lowering agricultural emissions by reducing the land area in agriculture, the PFSI would encourage landowners to sequester carbon in forest biomass (Trotter et al., 2005). Reversion of native forest also has other benefits, including on biodiversity (Hall, 2001) and water quality. These are not considered further here.

We simulate the effect of awarding farmers $50 for every tonne of carbon dioxide equivalent that is removed from the atmosphere by native forest regeneration from 2003 to 2012 as well as charging them for their livestock emissions as in the previous simulation. For this policy, farmers would be rewarded in proportion to the national average rate of carbon dioxide removals for every hectare that they set aside.

Under this scenario, if farmers set aside land in 2003, the annualized net present value over the next ten years would be $53 per hectare per year, assuming a 6% discount rate. This value can be compared with annual costs due to emissions charges of $149 and $433 per hectare annually in sheep/beef and dairy farming, respectively. These different charges and rewards alter relative returns, and we expect that some marginal dairy land would convert to sheep/beef land, and some marginal sheep/beef land would be allowed to regenerate native vegetation. Thus, in this scenario, there is potential to reduce emissions even more, with more land changing toward lower emitting land uses.

Surprisingly, this does not happen. When we compare net emissions in this scenario to net emissions from the previous scenario, which only includes the emissions charge, we find that introducing the reward actually increases emissions growth. In fact, not only does the policy result in greater emissions than the case of the emissions charge on its own, it results in greater emissions than the reference case. We find that this policy results in annual emissions growth during 2003 – 2012 greater than the reference case by about 0.1Mt of carbon dioxide equivalent; this is illustrated by the dotted line in the figure.

The reason for this unexpected result is that regenerating forest and scrub compete with plantation forestry for land. Regenerating forest and scrub expansion has occurred at the expense of plantation forestry expansion and consequently, plantation forestry area expands at a slower rate in this scenario than in the previous scenarios. Net emissions increase because young regenerating forest and scrub remove much less carbon dioxide from the atmosphere than young plantation forests. This is a short-term problem; in the long run, removals by naturally regenerating vegetation surpass those by plantation forestry. However, this effect would actually make meeting our obligations for the first Kyoto commitment period more difficult.

This result suggests that the PFSI has the potential to achieve a ‘perverse’ result during 2008–2012, by actually making New Zealand’s net position under the Kyoto Protocol worse. Rather than suggesting that the PFSI is poor policy, this result emphasizes that even policies with the potential to produce multiple environmental benefits such as the PFSI must be considered as part of an overall picture. In this case, the PFSI would be enhanced if plantation forestry were rewarded for carbon sequestration as well. Our preliminary results suggest that the government should consider also rewarding plantation forestry particularly if they want short-term emission gains.

Similarly, the impacts of levying a charge on land use related emissions from agriculture would ideally be examined in the context of carbon charges or emissions trading in the fossil fuel sector. This is not possible with any current model.

5 Summary

These illustrative simulations demonstrate that LURNZv1-climate is a useful tool for analysing potential greenhouse gas mitigation policies intended to reward or tax emissions resulting from land use activities. Our first simulation indicates that an agricultural emissions charge based simply on land use would be highly disruptive and may not be very effective in reducing emissions. Our second simulation shows that the inclusion of a reward for regenerating forest and scrub without a similar reward for plantation forestry might negatively impact on plantation forestry, increasing emissions growth in the short-run. This demonstrates the potential for policies to have unintended, and potentially perverse impacts when policies are not aligned across sectors.

The model results illustrate the importance of careful empirical analysis of potential policies, and emphasize the need for tools such as LURNZ that are applicable to New Zealand's unique situation. The results presented here are preliminary in that they illustrate the probable scale and direction of policy impacts but the exact size of those impacts may not be robust. We are currently developing a second version of LURNZ-climate, which will be much more robust, and thus lend more weight to our future results.

Finally, when developing LURNZv1-climate we used publicly available data whenever it was available. We did this to support our aim of making both LURNZ-climate and the LURNZ-climate database freely available for research purposes whenever possible. We hope others will use our data and model to explore these issues further. For more information, please visit www.motu.org.nz/land_use_nz.htm.

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