The Macroeconomic Impact on New Zealand of Alternative GHG Exchange Rate Metrics

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Abstract

We analyse the macroeconomic effects on New Zealand of using alternative metrics to price different greenhouse gases. Of particular interest is the interplay of different metrics with the effects of including or excluding agricultural non-CO_2 gases from an explicit carbon price. In order to fully capture world-wide effects we link a New Zealand specific general equilibrium model with a global integrated assessment model and a global spatially explicit land-use model. We find that switching from Global Warming Potentials (GWP) to Global Temperature Change Potentials (GTP) would not benefit New Zealand economically if agriculture is priced globally, as the lower emissions liability resulting from the GTP metric for New Zealand would be offset by smaller increases in commodity prices as agricultural production costs would be lowered globally. We also find that New Zealand economic welfare is higher if New Zealand is liable for its agricultural emissions (coupled with a relatively lower carbon price, high commodity prices and global participation), than if agriculture were excluded globally and New Zealand has to face a higher carbon price coupled with lower commodity prices. This finding holds irrespective of the choice of GHG exchange metric for other non-CO_2 gases, although it is marginally stronger under the GWP metric than under the GTP metric. The strength of the finding also varies directly with the price on emissions. Worse for New Zealand than either of those situations is if other countries are liable for agricultural non-CO_2 emissions, but choose to shelter them from a carbon price as this reduces the increase in world agricultural commodity prices from which New Zealand would be a net beneficiary.

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1. GLOBAL MODELLING

Introduction

One hundred-year Global Warming Potentials are used almost universally to compare emissions of CO_2 and non-CO_2 greenhouse gases, despite a range of well-known shortcomings (Shine 2009). Global Temperature Change Potentials (GTPs) are currently the most widely considered alternative metric (Forster et al. 2007; Fuglestvedt et al. 2010; IPCC 2009; Shine et al. 2005). Like GWPs, GTPs are based on bio-physical considerations and are relatively simple and transparent compared to metrics derived from economic cost-minimisation approaches, which may continue to make them attractive for climate policy. Recent work suggests that time-dependent GTPs can resemble metrics based on economic cost-minimisation approaches (Johansson 2011; van Vuuren et al. 2006a), but little work has been done to confirm how much fixed or time-dependent GTPs would in fact alter global or national costs of meeting prescribed stabilisation or emissions targets. Apart from affecting global mitigation costs, alternative metrics could be expected to have a large impact on national mitigation costs especially for countries, such as New Zealand, that have a large fraction of non-CO_2 gases in their emissions inventory. However, even less work has been conducted to test this assumption (with the exception of Godal and Fuglestvedt 2002). This study aims to address these gaps by evaluating:

a) global mitigation costs under alternative metrics (fixed and time-dependent GTPs) relative to GWPs for multi-gas abatement strategies that meet pre-defined global radiative forcing targets in the year 2100, and

b) the costs to New Zealand of meeting prescribed mitigation targets for the years 2020 and 2050 under those metrics. New Zealand has the largest fraction of non-CO_2 emissions of all Annex-I countries in its national emissions inventory (UNFCCC 2008).

Modelling approach and results: global perspective

We used the global integrated assessment model MESSAGE (Rao and Riahi 2006; Riahi et al. 2011; Riahi et al. 2007) to compare net global mitigation costs under fixed 100-year and time-dependent GTPs to those under default 100-year GWPs for two stabilisation targets (450 and 550ppm CO_2-eq in 2100) and alternative assumptions about the mitigation potential of agricultural non-CO_2 emissions.

Regional marginal abatement cost curves for agriculture in MESSAGE were updated using a detailed global modelling study for abatement potential and cost for agricultural soils, livestock, and paddy rice (Beach et al. 2008). A key uncertainty with regard to agricultural mitigation is the future evolution of its mitigation potential. We therefore tested the implications of either (1) no future improvement beyond the model potential in 2020, or (2) rapid improvement of mitigation potential at the same rates as described in van Vuuren et al. (2006b).

Metrics and exchange rates for individual GHGs were calculated a priori using the reduced-complexity climate model MAGICC version 6 (Meinshausen et al. 2011; Reisinger et al. 2010). For time-dependent GTPs, we assumed a target year of 2100 and global GHG concentrations following the RCP 3-PD pathway (van Vuuren et al. in press).

We find that fixed GTPs result in less abatement of CH_4 than GWPs and hence the model must place greater emphasis on CO_2 abatement to meet the same long-term radiative forcing target. This leads to higher mitigation costs and shadow prices for CO_2 and, as CO_2 mitigation dominates net global mitigation costs (Fisher et al. 2007), higher mitigation costs overall even though agriculture mitigation costs are lower. By contrast, time-dependent GTPs place an initially low but steadily escalating weight on CH_4 abatement towards 2100 and thus result in lower CH_4 emissions and concentrations in 2100 than under GWPs. The lower radiative forcing from CH_4 in 2100 permits less CO_2 mitigation and lower CO_2 shadow prices throughout the 21st century. This leads to lower net mitigation costs overall, but similar if not greater mitigation costs for agriculture. Table 1 lists results for different radiative forcing targets and assumptions about the evolution of agriculture abatement potential.

Table 1: Global Mitigation Costs

Differences in net present value (2010-2100) of global mitigation costs across all economic sectors for alternative metrics and assumptions about future evolution of agricultural mitigation potential. Mitigation costs using GWPs are given as absolute numbers (in US$ (2005)), while costs using fixed and time-dependent GTPs are expressed as percentage change relative to costs using GWPs.

radiative forcing target in 2100 (CO_2-eq)	no improvement in agricultural mitigation potential			rapid improvement in agricultural mitigation potential		
	GWPs	GTPs		GWPs	GTPs	
		fixed	time-dependent		fixed	time-dependent
450ppm	$11.9 trillion	+ 6.3%	- 4.6%	$ 8.9 trillion	+ 7.9%	- 3.9%
550ppm	$4.5 trillion	+ 4.7%	- 6.1%	$ 3.5 trillion	+ 9.7%	- 7.4%

These results are consistent with studies showing that time-dependent GTPs can resemble fully cost-effective exchange metrics (Johansson 2011; van Vuuren et al. 2006a), but to our knowledge this study is the first to quantify global net mitigation costs under fixed and time-dependent GTPs using a detailed global integrated assessment model. We note that the differences in costs from alternative metrics are non-negligible in absolute terms, but are much smaller than differences under alternative stabilisation targets and also smaller than uncertainty about mitigation costs arising from alternative assumptions about future mitigation potential of agricultural non-CO_2 emissions.

Details of this global modelling approach and further global results are described in Reisinger and Stroombergen (2011).

2. NEW ZEALAND MODELLING

Introduction

Even though alternative metrics have a smaller effect on global mitigation costs than other key uncertainties and decisions for climate policy, alternative metrics could be more important at regional and national scales, particularly for countries that may face binding economy-wide emissions targets under future agreements, but have large fractions of non-CO_2 emissions in their national inventories.

Agricultural non-CO_2 emissions constituted 47% of New Zealand's total emissions in 2009 (using GWPs), which is the highest fraction of non-CO_2 emissions amongst Annex I countries. Conditional on a comprehensive global agreement, New Zealand has accepted net emissions reductions targets of -10 to -20% by 2020, and -50% by 2050 relative to 1990 levels, through domestic efforts and emissions trading. The limited abatement potential for the key sources of non-CO_2 emissions (CH_4 from enteric fermentation and N_2O from urine deposits on grazing land) imply that alternative metrics could have major implications for the costs of meeting these economy-wide emissions targets.

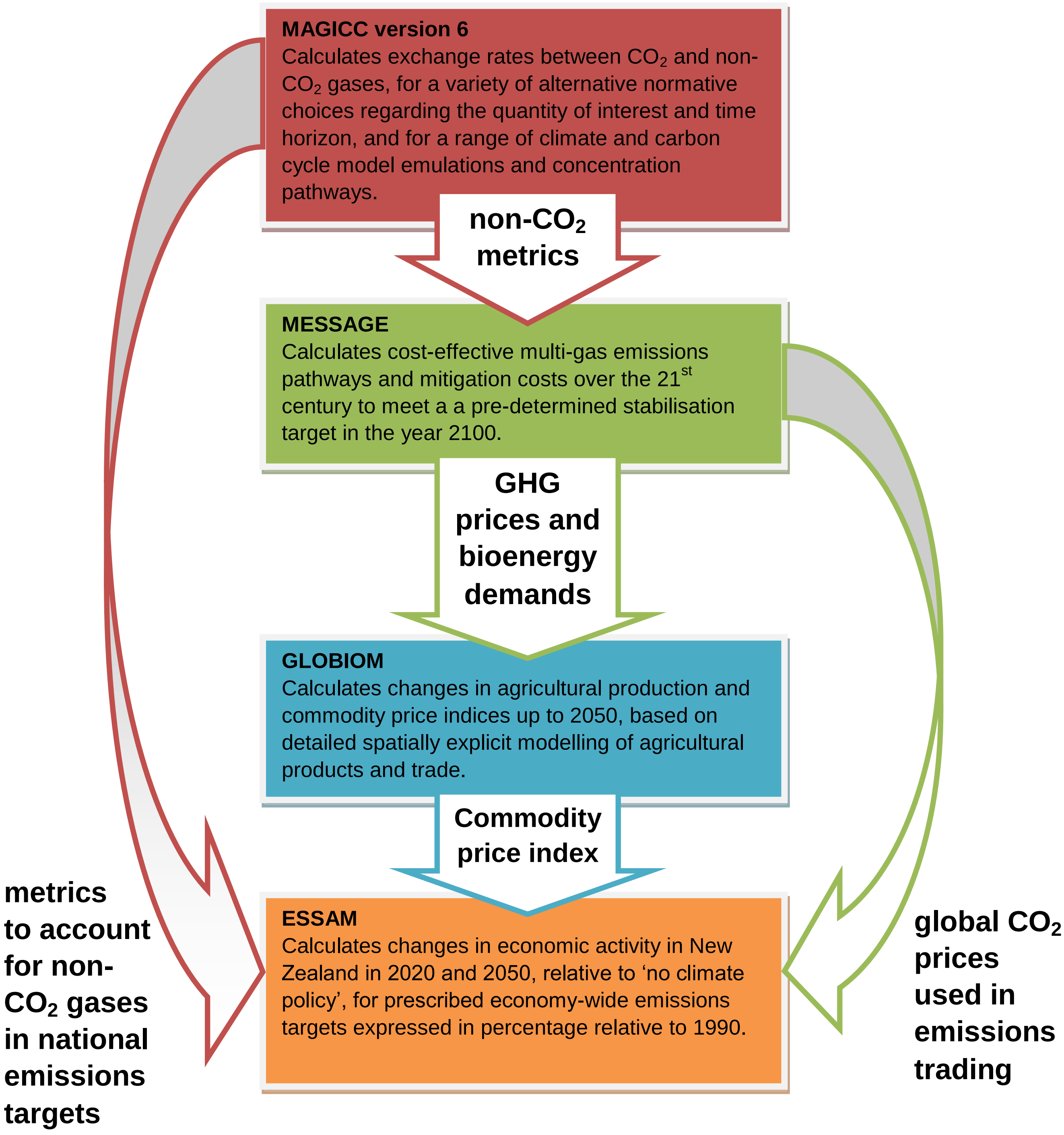
The potential effects of alternative metrics on New Zealand's costs of meeting future targets are complex. Alternative metrics would not only alter assigned amount units and gross and net future emissions levels, but also result in different GHG prices on international carbon markets. This would affect the costs to New Zealand of meeting part of its reduction targets through emissions trading. Moreover, metrics would affect agricultural commodity prices due to the added costs on agricultural production if GHG prices are passed on to producers in a global climate change response. This point is crucial for New Zealand as it derives more than half of its total export earnings from agriculture.

We employed a nested modelling approach to capture these interlinked effects of alternative metrics at the national scale, illustrated in Figure 1. As described in the previous section, the global integrated assessment model MESSAGE determines global mitigation costs, GHG shadow prices and biofuel demands under alternative metrics for a given long-term radiative forcing target (450ppm CO_2-eq, which gives a roughly 50/50 chance of warming not exceeding 2°C relative to pre-industrial levels). The partial equilibrium global agricultural and forestry model GLOBIOM (Havlík et al. 2010) is then used to estimate how alternative relative prices for CO_2, CH_4 and N_2O would affect agricultural production decisions and commodity prices at regional and global scales.

Finally, and constituting the main subject of this paper, a general equilibrium model of the New Zealand economy (ESSAM; Ballingall et al. 2009a; Stroombergen 2008) is used to calculate the costs to New Zealand of meeting its 2020 and 2050 emissions targets through a mix of domestic abatement and emissions trading under various GHG and commodity prices associated with alternative metrics.

The ESSAM modelling is described below.

Figure 1: Models and linkages



Scenario Specification

To limit the number of model runs, we analyse costs only under GWPs and fixed 100-year GTPs. For both metrics, we explore two policy assumptions: either agriculture is exposed fully to GHG prices in all countries, or all countries (other than New Zealand) choose to shelter agriculture from the costs of its non-CO_2 emissions (as is currently the case, see Johansson and Persson 2005; New Zealand is planning to include agriculture in its ETS in 2015 subject to a review of actions by other countries). Given the reluctance of countries to date to expose agriculture to emissions prices, we further test costs if agricultural non-CO_2 emissions were excluded from any abatement obligation in all countries (that is, they would not appear in New Zealand's emissions targets or assigned amount units, and no mitigation of non-CO_2 emissions occurs). We do not analyse costs for time-dependent GTPs as up to 2050, within the parameters chosen for this study, the exchange rates under this metric lie between those for GWPs and fixed GTPs.

All scenarios are compared to a 'Business as Usual' (BAU) scenario that has no international emissions obligations and no carbon prices. The BAU is not intended to be a forecast of the economy. Rather it is intended as a plausible projection of the economy in 2020 and 2050 in the absence of major external events and major policy changes.

The GWP and GTP gas exchange rates for the conversion of CH_4 and N_2O into CO_2 equivalents are shown in Table 2. For any given GHG concentration in the atmosphere, the different metrics imply different carbon prices and different agricultural commodity prices.

Table 2: GHG Exchange Rates

	CH_4	N_2O
GWP	25	298
GTP	7	318

Scenario 1: 2020, GWP exchange rates, 450 ppm

Scenario 2: 2020, GTP exchanges rates, 450 ppm

Scenario 2a: 2020, GTP exchange rates, 450 ppm, commodity prices as in Scenario 1

Scenario 3: 2020, GWP exchange rates, 450 ppm, other countries shelter agriculture from emissions charge and global CO_2 prices adjust accordingly to meet the same 450ppm target, but New Zealand remains liable for its agricultural emissions.

Scenario 4: As in Scenario 3 with agricultural non-CO2 emissions excluded from all international agreements and obligations.

Scenario 3a: Same as scenario 3, but using GTP metrics

Scenario 4a: Same as scenario 4, but using GTP metrics (for non-CO_2 gases for emissions from sectors other than agriculture)

The above scenarios are run for 2020, and analogous scenarios are run for 2050 (Scenarios 5-8). A further set of two scenarios explores the implications of a significant additional mitigation technology for methane emissions from enteric fermentation, were such a technology to become available some time before 2050 (Scenarios 9 and 10).

As noted above, for each scenario and time horizon, the shadow prices for the greenhouse gases CO_2, CH_4 and N_2O were derived from simulations using the global integrated assessment model MESSAGE and the commodity price changes were calculated for those greenhouse gas prices, and associated bioenergy demands, using the spatially explicit land-use model GLOBIOM.

Emissions Obligation

It is assumed that New Zealand takes on a 2020 obligation of responsibility for any net emissions that exceed 85% of 1990 gross emissions, irrespective of whether emissions are calculated under GWP or GTP gas exchange rates. That is, if domestic policies do not reduce emissions to 15% below what they were in 1990, New Zealand will have to purchase international emission permits to cover the excess.

Analogously, for 2050 the responsibility obligation is 50% of 1990 emissions.

New Zealand Emissions Policy

For both the 2020 and 2050 scenarios the parameters of the ETS as currently legislated are assumed to apply. In particular, agricultural emissions of methane and nitrous oxide enter the Scheme in 2015 with 90% free allocation of emissions units that is gradually reduced over time, but still provides for more than 50% of the base allocation amount in 2050. The carbon price in New Zealand is equal to the world carbon price so there is no New Zealand price maximum and there is no 2-for-1 concession as exists currently.

Forestry

For 2020 it is assumed that the ETS and the current age profile of eligible New Zealand forests is such as to generate net absorption of 16.1 MT. This amount is invariant across scenarios (NZIER and Infometrics 2011).

For 2050 no net effect from forestry is assumed as the net change in emissions from forestry stocks is as likely to be positive as negative.

Rest of the World Emissions Policies

The world price of carbon differs across the various scenarios as outlined in the following section.

Consistent with the global modelling we make the simplifying assumption that all other countries fully impose carbon prices on all sources of greenhouse gas emissions, including manufacturing industries that compete or could potentially compete with New Zealand; essentially paper, steel, aluminium, cement, and oil refining). This will affect the absolute cost to New Zealand of meeting any given emissions obligation, but is unlikely to have a material impact on the relative costs under different GHG exchange rates.

We explore alternative policies with regard to treatment of agricultural emissions; either that the world imposes a price on all agricultural emissions, or that the world excludes agricultural emissions from price measures.

Macroeconomic Closure

The following macroeconomic closure rules apply:

1. Labour market closure: Total employment is held constant at the BAU level, with wage rates being the endogenous equilibrating mechanism. Instead of fixed employment, wage rates could be fixed at BAU levels. This implies, however, that the long run level of total employment is driven more by climate policy than by the forces of labour supply and demand, which we consider unlikely.

2. Capital market closure: We assume that post-tax rates of return on capital held constant at BAU levels, with capital formation being endogenous.

3. External closure: The balance of payments is a fixed proportion of nominal GDP, with the real exchange rate being endogenous. This means that the cost of any adverse external shock such as having to buy emissions permits on the international market is not met simply by borrowing more from offshore, which is not sustainable in the long term.

4. Fiscal closure: The fiscal position is held constant at the BAU level, with personal income tax rates being endogenous. This prevents the results from being confounded by issues around the optimal size of government.

Modelling Results

The scenarios are split into two groups, those pertaining to 2020 and those pertaining to 2050, as our interest is primarily in the differences caused by GWP versus GTP at a point in time, rather than in the differences over time for some given set of GHG exchange rates.

2020 Scenarios

The scenario specification is summarised in Table 3.

Table 3: Scenario Specification

Scenario	GHG exchange rates	GHG prices ($/tonne of gas)			Commodity prices (relative to BAU)	
		CO_2	CH_4	N_2O	Livestock (dairy & meat)	Crops (horticulture)
1	GWP	$35	$866	$10321	18%	17%
2	GTP	$42	$295	$13346	16%	18%
2a	GTP	$42	$295	$13346	18%	17%
3	GWP	$77	$1927	$22966	14%	12%
3a	GTP	$88	$618	$27963	14%	12%
4	GWP	$77	$0 (ag. only)		14%	12%
4a	GTP	$88	$0 (ag. only)		14%	12%

In Scenarios 3 and 4 countries shelter agricultural non-CO_2 emissions from the emissions price. In scenario 3, this sheltering is done as a domestic policy choice; that is, countries are responsible for agricultural non-CO_2 emissions, but they choose not to impose a price on those emissions.

In scenario 4, we assume that agricultural non-CO_2 emissions are excluded by international policy agreement. That is, countries are not responsible for agricultural non-CO_2 emissions.

In both cases, international prices on CO_2 and non-CO_2 gases from sectors other than agriculture have to adjust so as to meet the same stabilisation target, as agricultural gases still contribute to overall radiative forcing, even if countries are not required or choose not to abate them.

Table 4 shows the results.

Scenarios 1 and 2

In scenario 2, the CO_2 price is higher than in scenario 1 due to the lower prices on non-CO_2 gases, which results in less abatement of those gases and hence requires more abatement of CO_2 to reach the same stabilisation target. The lower prices on methane emissions result in a slightly lower increase in livestock commodity prices.

The results show a net gain to New Zealand in both scenarios as the benefit of higher commodity prices easily outweighs the costs of a domestic carbon price coupled with an emissions responsibility target.

Interestingly, the gain in RGNDI is almost the same in both scenarios, but the gain is slightly greater under GWPs than under GTPs. This implies that the benefit of the smaller reduction (in terms of net BAU emissions compared to a -15% target) that would be required under the GTP option is outweighed by the higher carbon price and the slightly smaller rise in average commodity prices. New Zealand is affected more by dairy and meat prices than by horticultural prices.

Thus the contention that a lower weight on methane emissions would lower the cost to New Zealand of meeting any given proportionate emissions obligation, is not supported by these results – at least not for 2020 and under the assumption that the world as a whole applies a price on agricultural emissions.

It is also worth noting that under the parameters of the ETS, free allocation is intensity based. Thus the expansion in agricultural output in response to higher commodity prices occurs largely without that industry facing any additional emissions costs. That cost falls on the rest of the economy in the form of the need to buy emissions units from offshore.

Scenario 2a

This scenario has the GHG prices from Scenario 2 (i.e. applies the GTP metric), but the commodity prices from scenario 1. It is therefore an artificial scenario in the sense that the GHG prices and the commodity prices are not consistent with the results from the global models. Its purpose is purely to isolate the relative influence of the change in GHG prices and the change in commodity prices on the difference between Scenarios 1 and 2.

A shown in Table 4, the change in private consumption is less than in Scenario 2. To one decimal place the change in RGNDI is the same as in Scenario 2, although at two decimal places (which is spuriously accurate) the change is 0.73% compared to 0.65% in Scenario 2. The direction of these differences is consistent with the difference in commodity prices.

That the change in RGNDI is less than in Scenario 1 is interesting, as one might have assumed intuitively that a scenario that applies GTPs but uses the same commodity prices as Scenario 1 should result in a greater, not lesser welfare gain than Scenario 1, as the net emissions deficit to be financed by purchasing offshore emission units is smaller. While the emissions deficit cost is indeed smaller, this effect is not sufficient to offset the decline in the terms of trade between Scenarios 1 and 2a. Even though world agricultural prices are the same, the lower agriculture production costs under a GTP regime lead to an increase in output (as reflected by the increments in CH_4 and N_2O emissions), forcing exporters to move down the demand curve. Exporters are not pure price takers as no commodity group in the model is entirely homogeneous, nor perfectly substitutable with competing sources of supply.

It is worth noting, however, that all of these effects are very small and finely balanced, given the 2020 scenario specifications. Modelling those same effects for 2050 gives different results (see below).

Scenario 3

Scenario 3 has a similar specification to Scenario 1 (i.e. using the GWP metric) except that countries other than New Zealand choose not to apply a price on agricultural non-CO_2 emissions, although such emissions are still included in the calculation of global emissions and in countries' emissions responsibility obligations.

New Zealand continues to include Agriculture in the ETS, with free allocation.

This scenario applies a significantly higher CO_2 price as the abatement of CO_2 emissions has to increase and occur more rapidly as a result of the global non-abatement of agricultural non-CO_2 emissions. There is also a lower increase in commodity prices given the exclusion of agricultural non-CO_2 gases from price measures in all countries other than New Zealand.

The results in Table 4 now show a small macroeconomic loss as the carbon price is much higher than in Scenario 1 while commodity prices are lower. It is noteworthy though that the loss to New Zealand is relatively small, largely thanks to the pressure on commodity prices resulting from incentives for afforestation, and increased bio-energy demands.

Scenario 4

Scenario 4 is a variation on Scenario 3: here we assume that agricultural non-CO_2 emissions no longer form part of any international emissions obligations and hence are also excluded from the NZETS and New Zealand's base year and emissions target calculations. The carbon price and world commodity prices are the same as in Scenario 3 as in both scenarios the world aims to meet the same stabilisation target without applying a price on agricultural non-CO_2 emissions.

Comparing Scenarios 3 and 4 provides an estimate of the net cost to New Zealand of including or excluding agricultural emissions in its obligations (while assuming that the rest of the world is not pricing their agricultural emissions regardless of whether they are responsible for them). The comparison shows that New Zealand would benefit from agriculture being excluded from emissions obligations via international agreement, if the alternative is that the rest of the world *de facto* excludes agriculture but countries nominally retain responsibility for those emissions.

The difference in RGNDI is 0.5% and the difference in GDP is 0.2%. So the GDP gain from the removal of agricultural CH_4 and N_2O emissions from countries' and in particular, New Zealand's targets contributes about 40% of the total welfare gain (RGNDI), with the rest being attributable to the much smaller number of emission units that need to be purchased on the international market – 3.7 MT versus 14.5 MT.

Even though New Zealand would benefit from having agriculture excluded if other countries *de facto* shelter agriculture from price measures, it would be economically more beneficial for New Zealand if all countries included agriculture in a price measure. Comparing Scenarios 1 and 4 tells us that aggregate economic welfare is higher if New Zealand is liable for its agricultural emissions in the context of a relatively lower carbon price, high commodity prices and global participation, than if New Zealand has to face a higher carbon price coupled with lower commodity prices if agriculture is excluded globally. The difference in RGNDI is about 0.4%. This conclusion holds even though we assume in our model that New Zealand has no abatement technologies for agricultural emissions.

Scenarios 3a and 4a

We do not have corresponding GLOBIOM scenarios and hence commodity price changes for Scenarios 3a and 4a. We assume the same world commodity prices as in Scenarios 3 and 4, reasoning that:

- In both sets of Scenarios, 3 and 3a, and 4 and 4a, agriculture is effectively excluded from any direct price signal and thus additional production costs. Hence, to a first approximation, commodity prices should be identical across those four scenarios.

- The only difference between Scenarios 3 and 3a (and 4 and 4a) is that the global CO_2 price is slightly higher by about 14%. The higher CO_2 price would imply a marginally greater demand for bio-energy, and greater penalty on deforestation and incentive for afforestation. These drivers would tend to act against expansion of pastoral livestock and hence could increase commodity prices in scenarios 3a and 4a relative to scenarios 3 and 4.

- Given that the total increase in the cost of production for livestock is predominantly from prices on non-CO_2 gases, and the difference in CO_2 prices is only about 14%, the resulting change in commodity prices from Scenarios 3 and 4 to Scenarios 3a and 4a is likely to be within the margin of error.

Just as Scenario 3 produced a worse welfare outcome than in Scenario 1, so Scenario 3a produces a worse welfare outcome than in Scenario 2.

It is also noteworthy that New Zealand incurs a (small) net welfare loss if it is the only country to *de facto* put a price on its agricultural emissions, irrespective of whether GWP or GTP prevails. In contrast if agricultural emissions are excluded by international agreement, then New Zealand receives a small welfare increase, again irrespective of the GHG exchange metric. Comparing Scenarios 3 and 3a, New Zealand is economically slightly worse off if the rest of the world shelters agriculture from a price signal and the GTP metric is used to account for non-CO_2 emissions than if the GWP metric is used. The difference is only small though and minor changes in commodity prices associated with higher CO_2 prices (see above) could re-balance this outcome.

By construction the only significant difference between Scenarios 4 and 4a is the level of the price on CO_2 emissions, the effect of GWP v GTP having been made virtually irrelevant (for New Zealand) by the exclusion of non-CO_2 emissions from agriculture – although there are still some non-CO_2 emissions from waste, which are not irrelevant on a global scale. We find that in this case, New Zealand is in the same economic position regardless of the choice of metric for non-CO_2 gases from sectors other than agriculture. Intuitively the lower carbon price in Scenario 4 should deliver a better outcome. At two decimal places there is indeed a small (0.03%) difference in favour of Scenario 4, but the essence of the result is that the macroeconomic effects of a carbon price of $77/tonne are not significantly different from those when the price is $88/tonne.

Between Scenarios 3 and 4 the effects of totally removing agricultural non-CO_2 emissions from global and New Zealand's domestic GHG obligations raised RGNDI by 0.5%. Between Scenarios 3a and 4a the increase is only 0.2%, with none of it attributable to an increase in GDP. All of it is attributable to the drop in the number of emission units that need to be purchased on the international market – and this effect is smaller under GTP than under GWP.

Analogously to the above comparison, comparing Scenarios 2 and 4a tells us that aggregate economic welfare is higher if New Zealand is liable for its agricultural emissions in the context of a relatively lower carbon price, high commodity prices and global participation, than if New Zealand has to face a higher carbon price coupled with lower commodity prices if agriculture is excluded globally. The difference in RGNDI is about 0.3% under GTP compared to 0.4% under GWP.

Table 4: Summary of Results (2020)

	BAU	Scenario 1	Scenario 2	Scenario 2a	Scenario 3	Scenario 3a	Scenario 4	Scenario 4a
		GWP $35/t	GTP $42/t	GTP $42/t	GWP $77/t	GTP $88/t	GWP $77/t	GTP $88/t
				Commodity prices from Scenario 1	Other countries shelter agr emissions		Agr non-CO_2 excluded for all countries	
	(% pa on 2005/06)				% Δ on BAU			
Private Consumption	2.6	1.1	0.9	1.0	-0.2	-0.2	0.6	0.5
Exports	3.7	1.0	1.3	1.4	0.2	1.1	-0.3	-0.5
Imports	3.7	2.6	2.6	2.8	1.1	1.4	1.7	1.7
GDP	2.8	0.3	0.3	0.3	-0.4	-0.3	-0.2	-0.3
RGNDI	3.2	0.8	0.7	0.7	-0.1	-0.2	0.4	0.4
	MT	MT	MT	MT	MT	MT	MT	MT
CO_2e 1990 (GWP)		65.3			65.3		23.7	
CO_2e 1990 (GTP)			46.7	46.7		46.7		23.7
AAU (GWP)		55.5			55.5		20.1	
AAU (GTP)			39.7	39.7		39.7		20.1
CO_2e 2020 (GWP)	90.9	91.0 (0.1%)			86.1 (-5.3%)		39.9 (-16.2)	39.2 (-17.6)
CO_2e 2020 (GTP)	69.5		67.1 (-3.4%)	67.4 (-3.0%)		63.7 (-8.4%)		
Forestry net		-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1
Net deficit		19.4	11.3	11.6	14.5	7.8	3.7	3.0
- as % of BAU		21.3%	16.3%	16.7%	16.0%	11.2%	7.9%	6.5%
CH_4 & N_2O (GWP)	44.9	49.2 (9.6%)			47.8 (6.6%)		NA	
CH_4 & N_2O (GTP)	23.4		26.0 (10.9%)	26.2 (11.8%)	-0.2	26.0 (10.9%)		NA

2050 Scenarios

The scenario specification is summarised in Table 5 and the results presented in Table 6. Scenarios 5-8 are specified identically to Scenarios 1-4 respectively, but the GHG prices and commodity prices are different.

Table 5: Scenario Specification

Scenario	GHG exchange rates	GHG prices ($/tonne of gas)			Commodity prices (relative to BAU)	
		CO_2	CH_4	N_2O	Livestock (dairy & meat)	Crops (horticulture)
5	GWP	$150	$3744	$44606	94%	57%
6	GTP	$181	$1277	$57667	68%	61%
6a	GTP	$181	$1277	$57667	94%	57%
7	GWP	$333	$8330	$99256	51%	39%
7a	GTP	$381	$2667	$121158	51%	39%
8	GWP	$333	$8330	$99256	51%	39%
8a	GTP	$381	$2667	$121158	51%	39%
9	GWP	$126	$0 (ag. only)		94%	57%
10	GTP	$146	$0 (ag. only)		68%	61%

Scenarios 5 and 6

Both scenarios show a macroeconomic gain that is considerably higher than the corresponding 2020 scenarios. Thus the positive effect of the higher commodity prices outweighs the negative effect of the higher GHG prices by even more in 2050 than in 2020.

Again it is clear and noteworthy that switching from a GWP metric to a GTP metric does not benefit New Zealand as the carbon price is higher and the increase in commodity prices is smaller than under GWP, provided full international pricing of agricultural non-CO_2 emissions prevails.

Scenario 6a

Like Scenario 2a, Scenario 6a is an artifice, having the GTP carbon price from Scenario 6, but the world commodity prices from Scenario 5. Unlike the 2020 case, however, the results of Scenario 6a do not fall in between the two scenarios from which it is constructed. It is better than either of them.

This time the results are as expected with the change in RGNDI exceeding that in Scenario 5. Although the CO_2 price is higher in Scenario 6a than in Scenario 5, $21,200m has to be spent on purchasing emission units from offshore under Scenario 5, compared to only $17,700m of units that would need to be purchased under Scenario 6a. This easily outweighs a reduction in the terms of trade caused by agricultural exports moving down the demand curve.

This is not the case for the analogous 2020 scenarios where at $490m and $680m for the purchase of credits offshore in Scenarios 2a and 1, respectively, the difference in costs for credit purchases is not large enough to offset the decline in the terms of trade.

An inference which may be drawn then is that absent any changes in world agricultural commodity prices, a switch from GWP to GTP does not benefit New Zealand if carbon prices are low (in the order of NZ$30-60 per tonne of CO_2), but at higher carbon prices in excess of NZ$100 per tonne of CO_2 New Zealand does benefit from a GTP regime.

Unfortunately this benefit is likely to be offset by less favourable changes in commodity prices under GTP (Scenario 6 versus Scenario 6a) if the rest of the world also applies a price on agricultural emissions and hence production costs fall globally under GTP relative to GWP. It needs to be noted though that full international pricing of agricultural non-CO_2 emissions may be a tentative prospect for 2050 but appears very unlikely for 2020, which is why alternative scenarios where the world excludes agricultural emissions from any price measure are also considered in this study.

Scenario 7

Scenario 7 is analogous to Scenario 3; countries are responsible for agricultural non-CO_2 emissions, but no countries except New Zealand impose a price on those emissions. In New Zealand agriculture remains in the ETS with free allocation. By 2050 free allocation still amounts to over 60% of the initial free allocation – on an intensity basis.

While Scenario 3 shows only a modest reduction in welfare when compared to Scenario 1 (and only a very small reduction in welfare relative to BAU), the difference between Scenarios 7 and 5 is much starker. The relative change in RGNDI between Scenarios 5 and 7 is -9.2% (and -5.6% for Scenario 7 relative to BAU), compared to only -0.9% between scenarios 1 and 3. In other words, the negative impact on New Zealand if the rest of the world chooses not to impose a price on agricultural emissions, but New Zealand does so, is much greater in 2050 than in 2020.

The contrast is driven by both the lesser increase in commodity prices that occurs in 2050 than in 2020, if agricultural emissions are sheltered by the rest of the world compared to a scenario where they are not, and by the marked lift in the carbon price from $150/tonne to $333/tonne (albeit that the relative change in carbon prices is the same between Scenarios 1 and 3, and between Scenarios 5 and 7).

It has to be conceded that the changes in the relative prices of goods and services throughout the whole economy under such a high carbon price would be so great that the parameter values in the model's demand functions and production functions may no longer be reasonable approximations of behaviour. In particular we could expect to see the development of some step-change mitigation technologies and potential behavioural changes that affect the demand for various products and services. Nevertheless we should not totally disregard the model's estimated effects of a $333/tonne carbon price. What we can infer is that the true effects are probably less severe than estimated by the model.

In the context of this caveat we look below at the effects of a new mitigation technology for enteric fermentation in Scenarios 9 and 10.

Table 6: Summary of Results (2050)

	BAU	Scenario 5	Scenario 6	Scenario 6a	Scenario 7	Scenario 7a	Scenario 8	Scenario 8a
		GWP $150/t	GTP $181/t	GTP $181/t	GWP $333/t	GTP $381/t	GWP $333/t	GTP $381/t
				Commodity prices from Scenario 5	Other countries shelter agr emissions		Agr non-CO_2 excluded for all countries	
	(% pa on 2005/06)				(% Δ on BAU)			
Private Consumption	2.5	4.6	4.2	5.2	-7.1	-5.6	1.0	0.3
Exports	2.8	9.7	10.0	11.1	11.4	13.1	7.4	8.0
Imports	3.1	11.1	10.8	12.6	-3.0	-0.5	5.2	4.6
GDP	2.3	2.6	2.4	2.9	-0.7	0.0	1.3	1.1
RGNDI	2.6	3.6	3.3	4.1	-5.6	-4.5	0.8	0.2
	MT	MT	MT	MT	MT	MT	MT	MT
CO_2e 1990 (GWP)		65.3			65.3		23.7	
CO_2e 1990 (GTP)			46.7	46.7		46.7		23.7
AAU (GWP)		32.7			32.7		11.9	
AAU (GTP)			23.4	23.4		23.4		11.9
CO_2e 2050 (GWP)	147.9	173.9 (17.6%)			149.6 (1.1%)		56.5 (-21.5%)	
CO_2e 2050 (GTP)	108.9		115.6 (6.1%)	121.1 (11.2%)		109.4 (0.5%)		56.2 (-22.0%)
Net deficit		141.2	92.2	97.7	116.9	86.0	44.6	44.3
- as % of BAU		95.5%	84.7%	89.7%	79.0%	79.0%	64.8%	64.3%
CH_4 & N_2O (GWP)	79.0	114.7 (45.2%)			94.1 (19.2%)		NA	
CH_4 & N_2O (GTP)	40.0		57.2 (43.1%)	61.9 (54.7)		53.7 (34.3%)		NA

Table 7: Summary of Results (2050) (agricultural abatement technology)

	BAU	Scenario 5	Scenario 6	Scenario 9	Scenario 10
		GWP	GTP	GWP	GTP
		$150/t	$181/t	$126/t	$146t
				Lower CH_4	Lower CH_4
	(% pa on 2005/06)	(% Δ on BAU)			
Private Consumption	2.5	4.6	4.2	6.5	5.6
Exports	2.8	9.7	10.0	9.1	9.0
Imports	3.1	11.1	10.8	13.3	12.2
GDP	2.3	2.6	2.4	3.1	2.8
RGNDI	2.6	3.6	3.3	5.1	4.4
	MT	MT	MT	MT	MT
CO_2e 1990 (GWP)		65.3		65.3	
CO_2e 1990 (GTP)			46.7		46.7
AAU (GWP)		32.7		32.7	
AAU (GTP)			23.4		23.4
CO_2e 2050 (GWP)	147.9	173.9 (17.6%)		152.3 (3.0%)	
CO_2e 2050 (GTP)	108.9		115.6 (6.1%)		109.5 (0.5%)
Net deficit		141.2	92.2	119.6	86.1
- as % of BAU		95.5%	84.7%	80.9%	79.1%
CH_4 & N_2O (GWP)	79.0	114.7 (45.2%)		92.5 (17.2%)	
CH_4 & N_2O (GTP)	40.0		57.2 (43.1%)		50.7 (26.7%)

Scenario 8

Scenario 8 is a variation on Scenario 7, analogous to the relationship between Scenarios 4 and 3 respectively: agricultural non-CO_2 emissions are excluded from the NZETS and New Zealand's target as they no longer form part of any international emissions obligations.

We find that as in 2020, New Zealand would benefit from agriculture being excluded from emissions obligations via international agreement, if the alternative is that the rest of the world *de facto* excludes agriculture but countries nominally retain responsibility for those emissions. Running the same comparisons as before, RGNDI and GDP are 6.4% and 2.0% (respectively) higher than in Scenario 7. Thus 31% of the welfare benefit from removing the charge on agricultural CH_4 and N_2O emissions is attributable to the change in GDP, which is lower than that the 40% observed for 2020. Given the bigger reduction in emissions liability in 2050 when agricultural non-CO2 is removed from international obligations, this is not surprising.

Also similar to 2020, comparing Scenarios 5 and 8 tells us that aggregate economic welfare is higher by 3.6% if New Zealand is liable for its agricultural emissions in the context of a relatively lower carbon price and higher commodity prices resulting from full pricing of all agricultural non-CO_2 emissions globally, compared to facing a higher CO_2 price coupled with lower commodity prices if agriculture is excluded everywhere. This difference is an order of magnitude larger than for 2020, indicating that in the long-term, achieving a globally comprehensive agreement on climate change becomes more and more important for New Zealand.

This finding is consistent with a finding in NZIER and Infometrics (2011) that as the international carbon price rises the welfare cost of excluding agricultural non-CO_2 emissions becomes progressively higher, irrespective of what the rest of the world is doing with regard to agricultural non-CO_2 emissions. However, that work does not consider the effects of any reduction in commodity prices when the whole world excludes agricultural non-CO_2 emissions, which clearly has an additional negative effect on New Zealand.

Scenarios 7a and 8a

As before we do not have corresponding GLOBIOM scenarios for Scenarios 7a and 8a. Thus we assume the same world commodity prices as in Scenarios 7 and 8, for the same reasons as for the 2020 runs.

The relative change in RGNDI between Scenarios 6 and 7a is -7.8%, somewhat smaller than the -9.2% change between Scenarios 5 and 7. This is consistent with the results for 2020 whereby the effect of countries being responsible for agricultural non-CO_2 emissions, although no countries except New Zealand imposing a price on those emissions, is larger under GWP than under GTP. The main reason for this is smaller net deficit under the GTP metric and hence lower cost of purchasing emissions permits from overseas. Nevertheless the change in RGNDI in 2050 is still much larger than the change in 2020, as also occurred under GWP, which is attributable to the very high price of NZ$381/tonne of CO_2.

Scenario 8a with agricultural non-CO_2 emissions completely excluded from country obligations shows a gain in RGNDI of 4.7% compared to Scenario 7a. This is not as large as the corresponding change under GWP, as is also the case in the analogous 2020 scenarios.

Comparing Scenarios 6 and 8a also reinforces the previous message that aggregate economic welfare is higher if New Zealand is liable for its agricultural emissions in the context of a relatively low carbon price, high commodity prices and global participation, than if New Zealand has to face a higher carbon price coupled with lower commodity prices if agriculture is excluded globally. The difference in RGNDI is about 3.1% under GTP compared to 2.8% under GWP. That the difference under GTP is the larger of these two numbers is a reversal of the result for 2020.

This seems counter intuitive as a lower weight on CH_4 and N_2O would suggest a smaller gain from ignoring them completely. In level terms the intuition is correct as economic welfare is higher in Scenarios 5 and 8 than in Scenarios 6 and 8a respectively. However, the gain from a reduction in the carbon price from $381 to $181 (under GTP) exceeds the gain from a reduction from $333 to $150 (under GWP). For the 2020 scenarios the changes in the carbon price are much closer in absolute terms between GWP and GTP.

In summary, New Zealand is better off under GWP than under GTP if agriculture emissions are excluded via international agreement from all abatement obligations, but by 2050 the relative gain from removing agricultural non-CO_2 emissions from any GHG obligations is greater under GTP.

Scenarios 9 and 10

We return now to Scenarios 5 and 6, and look at how the results change under the assumption that from 2030 onwards there is a global mitigation technology which reduces enteric fermentation emissions by 30% at a cost of US(2005)$70/t CO_2e.

There is full international participation with all countries pricing all emissions, and every country benefits from the new technology with equal effectiveness.

Scenario 9 is set in a GWP context while Scenario 10 is set in a GTP context. Apart from GHG prices, the scenario specifications are as in Scenarios 5 and 6 respectively (i.e. we assume that commodity prices would not (yet) have been affected by the availability of this mitigation technology). As the GHG prices are slightly lower than in Scenarios 5 and 6, we might expect some flow-on to lower commodity prices as well. However with the cost of the new technology being not much cheaper than the carbon price the effect on commodity prices would be small. Thus we have not re-run the GLOBIOM model to calculate commodity price changes for these specific assumptions.

The results are shown in Table 7.

In Scenario 9 the welfare gain (RGNDI) is about 40% higher than in Scenario 5, with the emissions benefit of the new technology and the lower carbon price contributing to the improvement in roughly equal proportions.

In Scenario 10 the welfare gain is about one third higher than in Scenario 6. Again the split is about equal in terms of the relative contribution of the lower emissions price and the lower quantity of emissions attributable to the new technology.

In absolute terms the relative welfare gain between Scenarios 6 and 10 is smaller than between Scenarios 5 and 9. This makes sense. With the lower weight on CH_4 emissions under GTP, the value of a technology that reduces CH_4 emissions is less than under GWP. Acting in the opposing direction, but of less significance, is the larger reduction of the carbon price in the GTP case – from $181 to $146 compared to a reduction from $150 to $126 in the GWP case.

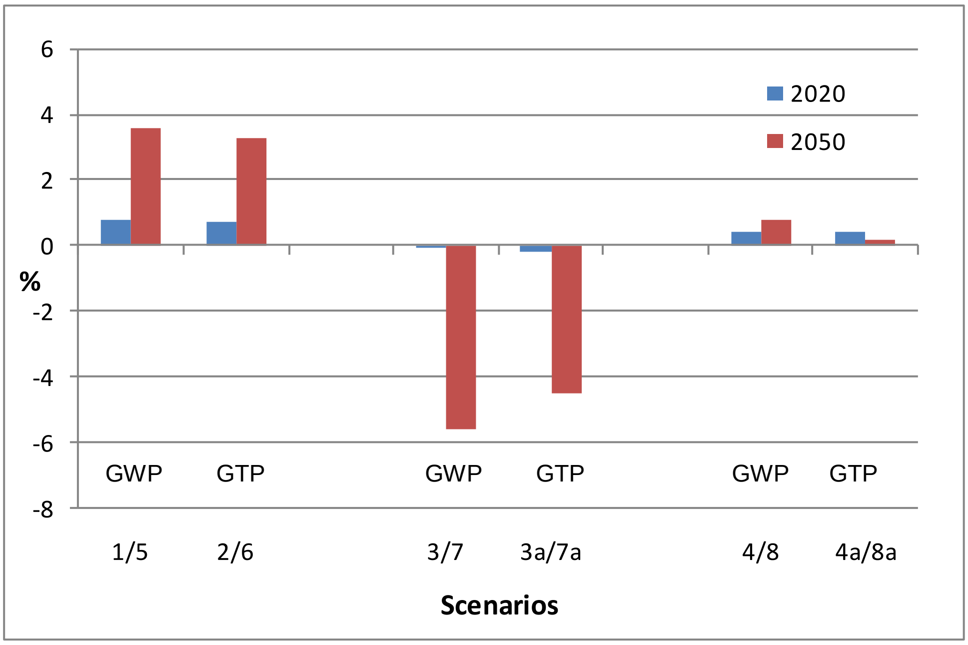
This means that if a significant new abatement technology for CH_4 from enteric fermentation were to become available, New Zealand would gain more from this technology under a GWP metric than under a GTP metric.

Nevertheless the important effect that a new technology can have on economic welfare is clearly demonstrated under both GHG metrics. The results also underline the point made earlier that ignoring new abatement technologies under high carbon prices, even if those technologies are not cost-free, could significantly overstate the welfare cost of mitigating emissions.

2020 v 2050

While the main focus of the research has been on GWP versus GTP, the foregoing discussion has also noted some contrasts between the modelling results for 2020 and those for 2050. The RGNDI results are shown in Figure 1.

Figure 1: Changes in RGNDI



It is clear that for four of the six scenario specifications the effects of the various input assumptions on RGNDI in 2050 are considerably larger than the effects in 2020. For the core scenarios (1 & 2 for 2020 and 5 & 6 for 2050) the difference in horizon years completely dominates the difference between GHG exchange metrics. This is also true for the scenarios where other countries shelter agriculture from an emissions charge, but New Zealand still includes agriculture in the ETS, albeit with free allocation (Scenarios 3 & 3a for 2020 and 7 & 7a for 2050). Of course the main reason is the much higher GHG prices in 2050.

Figure 1 graphically illustrates that the GTP metric generally mutes the economic effect on New Zealand in both directions: where New Zealand might gain from climate change policy settings, it gains by less under the GTP metric, but where it would lose, it would also lose by less. Overall though, whether or not other countries impose an explicit price on agricultural non-CO_2 emissions has a bigger effect on New Zealand's economic welfare than the choice of GHG exchange metrics, especially under higher GHG prices.

Only in the scenarios where agricultural non-CO_2 emissions are totally excluded is the effect of the timing difference (GHG prices) comparable to the effect of the choice of GHG exchange metrics (Scenarios 4 & 4a for 2020 and 8 & 8a for 2050). One might argue that is a trivial result: if agricultural non-CO_2 emissions are excluded, their conversion factors into CO_2 equivalents are irrelevant. However, the conversion factors do affect the global price on CO_2 that is required to meet a given stabilisation target, and this price flows back into the New Zealand economy. However, our results demonstrate a relative insensitivity to that CO_2 price in comparison with the other assumptions made in our study.

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