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18 December 2020

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Review of Models and Modelling

Dear Anita

Thank you for the opportunity to review the modelling undertaken by the Commission.

To confirm our earlier discussions, I haven't seen anything so seriously suspect about the modelling that it would prevent the Commission from publishing the work done to date. To be even surer I requested a model comparison and an additional run of the C-PLAN model, notably:

1. An industry by industry comparison of results for the Reference scenario from C-PLAN with the Base Case scenario from ENZ. Eventually a similar comparison between TP1 and an analogous scenario from ENZ (Headwinds?) would be also be useful.
2. A re-run of TP1 with half the carbon price over the period to 2050 so that gross emissions are endogenous. No other changes to exogenous settings, including forestry removals. The aim here is to see how far off the 2050 target gross emissions would be, and also to understand the importance of different industries in the abatement equation, excluding changes in agricultural CH_4 which are largely exogenous.

I address the outcomes of these analyses below. In my first draft I also had a number of other questions which are repeated below along with answers, either provided by the Commission or as interpreted by me based on data provided.

Modelling methodology

As one would expect there is no automatic link between the ENZ and C-PLAN models. Instead the link is described as a 'loose coupling'. The main use of ENZ is to provide inputs into C-PLAN in areas such as EV uptake and land use.

A good approach is to compare results at the industry level from the two models and reconcile any major differences. This is discussed further below. Of course differences are to be expected. For example general equilibrium effects are omitted from ENZ, and production

function elasticities in C-PLAN are unlikely to align perfectly with known production technologies in ENZ.

As the model coupling develops there may be opportunities for inputting some of the C-PLAN results back into ENZ – for example electricity prices.

CPLAN model

The C-PLAN model has the core requirements of an applied general equilibrium model. It has the standard mix of households who maximise utility, producers who maximise profit, international trade, and a government sector. Industry production functions are of a nested variety permitting various degrees of substitution between inputs. Similarly consumers can substitute between different goods and services.

A model audit is not warranted (nor requested) and in any case functional forms and parameter values can always be debated. To understand and have confidence in the model's results requires:

- Knowing how the model's closure rules are set.
- Observing how sensitive the results are to changes in some key inputs.

These aspects are discussed below.

Macroeconomic closure

The closure settings accord with standard GE modelling practice. Between scenarios there is no change in total hours worked, no change in the government's fiscal position and no change in the international current account balance (with the real exchange rate being endogenous).

Frequently in GE modelling the capital closure rule links the post-tax rate of return to a world rate of return, acknowledging that New Zealand is part of the international capital market. Thus a potential fall in the rate of return is forestalled by lower investment and thus a lower capital stock.

Question 1: What happens to rates of return across the scenarios and does the capital stock change across scenarios?

> *Industries that are subject to exogenous changes such as electricity generation and farming with a methane inhibitor have endogenous relative rates of return. The rest have fixed relativities, but across scenarios the rates of return in these industries change by between -3.1% and -1.4% relative to BAU.*
>
> *Comparing those changes with the changes in the total cost of capital relative to BAU, which are –3.6% to -1.6%, implies that the capital stock is more or less constant across scenarios. Coupled with unchanged employment, the small changes in GDP across the scenarios (-0.9% to -0.3%) are unsurprising.*

GDP effects

In some scenarios the domestic carbon price diverges substantially from the world carbon price which rises to US$250 by 2050. In the BAU scenario New Zealand EITE (emissions intensive, trade exposed) industries have a competitive advantage, but in some other scenarios that advantage flips. This has little effect on the output of EITE industries as they either exit New Zealand well before 2050 (aluminium and methanol production) or have output constrained to near BAU levels (cement and steel).

These exogenous assumptions are a further reason why changes in real GDP are not much different between the low and high carbon price scenarios, compared to past modelling by NZIER and Infometrics. Scenarios TP3 and TP4 which have ETS1 carbon prices over $800/tonne do not see reductions in GDP of more than 1% in 2050.

Other exogenous changes such as emissions from waste, a higher uptake of EVs and the disappearance of gas-fired electricity generation (from ENZ) also play a significant part in enabling the economy to adjust to those very high carbon prices at little overall cost – not much of the economy is left exposed to such prices. Without these and other changes in technology the model would likely produce larger macroeconomic effects. In that connection:

Question 2: What happens to other macroeconomic variables such as private consumption, gross investment and the terms of trade in the various scenarios?

> *The changes in the components of expenditure GDP relative to BAU are comparable to the changes in GDP. However, the changes in the terms trade range between -3.5% and -3.2% relative to BAU.*
>
> *Assuming exports are around 30% of GDP implies that the fall in real gross national disposable income (RGNDI, but excluding net factor payments which are not in the model) is about 1% more than that in GDP. For example in T1 the change in GDP is -0.3%, but the change in RGNDI would be around 1.3%. Such changes are more aligned with those in previous studies.*

Question 3: Also what is the value of the lump sum transfer of revenue from the carbon charge back to households?

> *The values are $8bn-$9bn in TP1 and TP2, and around $16bn in TP3 and TP4. The calculations seem correct.*

ENZ and C-PLAN output comparison

There are a number of ways to compare results from the ENZ and C-PLAN models.

1. Base year calibration of emissions from each model.
2. The change in emissions from the base year to 2050 in the a BAU (Reference) scenario, in either absolute changes or proportionate changes.
3. The change in emissions in 2050 between alternative scenarios, in either absolute changes or proportionate changes.

Figure 1 shows the second option in terms of percentage changes. The changes in total emissions are very close; -20% in C-PLAN and -24% in ENZ. However, ignoring international transport, which is outside New Zealand's carbon budget, there are some significant differences:

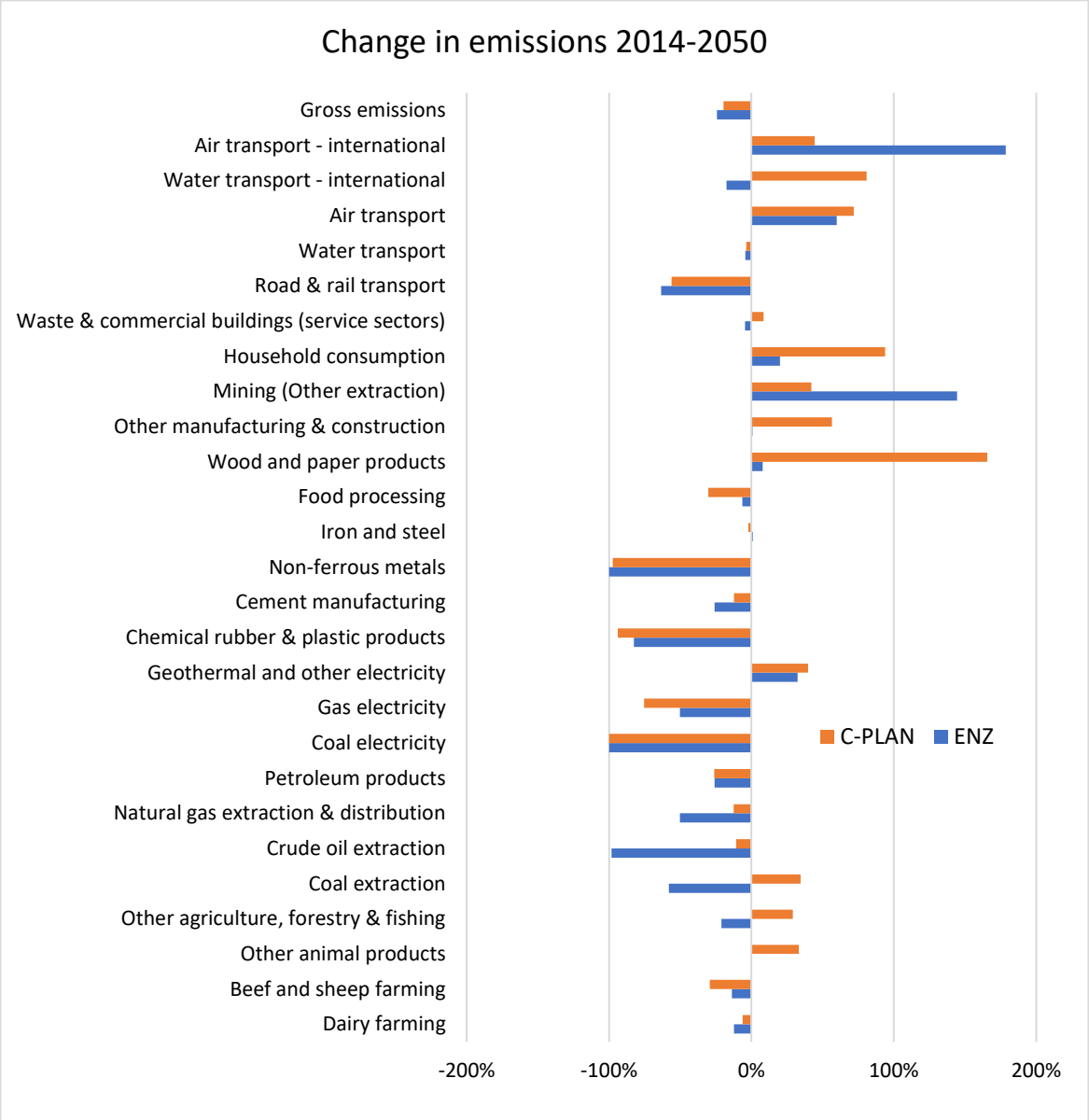
- household consumption
- other manufacturing and construction
- wood and paper products
- food processing
- all of the mining industries

- other agriculture, forestry and fishing
- other animal products

It is possible that C-PLAN is projecting higher economic growth which pulls up activity and emissions in the household sector, as well as in industries such as other manufacturing and construction, forestry products, and mining. Food processing is an exception as C-PLAN depicts a bigger emissions reduction than ENZ.

To some extent differences may also be attributable to variations in how industries are defined in the two models.

Figure 1



Question 4: As noted above identical results should not be expected, nor sought, but are there any other obvious reasons for the differences?

The following reasons have been offered:

- *Definition differences: Household consumption in C-PLAN includes private vehicles, other mining is included in construction in ENZ, food processing and other animal products do not correspond exactly in the two models.*
- *EV uptake has been revised in ENZ.*
- *Wood processing is unconstrained in C-PLAN, but in ENZ this industry has flat emissions.*
- *Coal and oil exports continue in C-PLAN, possibly not in ENZ.*
- *Food processing difference occurs before 2025 (could be related to assumed fuel substitution in ENZ – see ENZ discussion below).*

In absolute terms the models are consistent, with both projecting the largest emission reductions to occur in road transport, pastoral agriculture, and electricity generation – in descending order.

C-PLAN half price scenario

The price path to 2050 ending at $338 in Scenario TP1 leads to gross emissions of 24.3Mt (30% lower than under BAU) which, with forestry removals of the same amount, meets the 2050 target of net zero emissions (excluding biogenic methane). This is by design. Halving the price leads to gross emissions of 27.8mt, so net emissions are short of the target by 3.5Mt.

Looking at the scenarios in reverse order, a price of $169 which is $134 above the BAU price of $35, reduces emissions by 7.0Mt. Doubling the price to $338 reduces emissions by only a further 3.5Mt, so there is a clearly a rising marginal abatement cost curve – as expected.

Question 5: What is the change in GDP relative to BAU in the half price scenario?

*The change is **-**0.2% relative to BAU, so consistent with TP1.*

The incremental change of 3.5Mt has the following components:

- 1.07Mt of CO_2 commercial road transport.
- Seven industries see a change in CO_2 emissions of more than 0.1Mt, for a combined total of 0.98Mt.
- Non-biogenic methane changes by 0.20Mt CO_2e.

These changes combined account for 64% of the total change.

In terms of proportionate changes, the average is 15% and highest is 100%, the latter being households abandoning fossil fuelled transport.

These results seem plausible in the context of production and consumption substitution elasticities that are estimated from historical data. They also underline the importance of being able to incorporate into GE models historically unprecedented changes such as a large scale shift from fossil fuelled vehicles to electric vehicles. Another example is new methane reduction technologies in agriculture (vaccines and modified grass varieties).

ENZ model

Bottom-up modelling with backstop technologies such as in ENZ is certainly a useful modelling approach, but it does depend on knowing what those technologies might be. In dairy

processing for example there seems to be no ability in ENZ for substitution of energy-intensive evaporation or the transport of liquid milk over long distances, in favour of reverse osmosis, as was introduced at the Tuamarina dairy factory after a fire in 2004.

An energy efficiency parameter or fuel substitution elasticity in a standard GE model production function could capture the effects of such a change without knowledge of that particular technology.

The point is that one should not necessarily expect a GE model to always understate the possibilities for input substitution in production (or consumption).

EBIT

In ENZ land use change in agriculture and forestry is exogenous, encapsulating policies such as the proposed essential freshwater standards, with on-farm responses such as changes in output per hectare and changes in EBIT/ha.

The price of biogenic CH_4 emissions is endogenous (to meet the target), which can also lead to changes in EBIT/ha.

Question 6: Are changes in EBIT/ha in C-PLAN ever large enough to have potential feedback effects to land use assumptions in ENZ?

> *I understand this is being investigated.*

Harvested wood products

The carbon stored in harvested wood products is simulated by changing the factor for averaging emissions from 17 years to 22 years, but there is no feedback to this number from changing the product mix, for example as could occur if more forestry is used to produce biofuels.

Question 7: Are changes in the forestry product mix in C-PLAN ever large enough to potentially affect the assumed forestry removals of CO_2 in ENZ?

> *Across the scenarios changes in output from the forestry industry relative to BAU vary from -8% to -3% relative to BAU, and the share of its output going to the wood processing industry is confined to a narrow range of 91.2% to 91.5%. Thus the feedback effect on assumed CO_2 removals is negligible.*

DIM model

The Distribution model seems appropriate for what it is intended to do.

There is, however, one potentially important issue that it does not address, notably the effect of recycling revenue from the carbon charge back to households. My understanding is that this is not possible to simulate with the model at its current stage of development.

This is actually quite a tricky modelling extension. The industry results that are distributed by DIM (across dimensions such as employment by gender or region) already capture the effects of recycling revenue back to the household sector in aggregate – via the lump sum transfer. That aggregate picture can be theoretically consistent with many ways of distributing the revenue amongst different income groups and household types.

However, It can also be theoretically inconsistent with any given distribution. For example if the recycling is targeted to low income households the aggregate propensity to consume may change, along with the mix of consumer expenditure.

Hence modelling revenue recycling in DIM (if that is pursued) would entail constraining DIM in some way and/or iterating between DIM and C-PLAN. This is probably a second order issue.

Future research

Sensitivity analysis

Overall the results of the modelling system are heavily influenced by exogenous assumptions, whether about land use, industry survival, vehicle travel, or new technologies and their uptake. This is probably unavoidable when dealing with economic responses to something as historically unprecedented as climate change. It does imply, however, that sensitivity analysis is crucial.

Granted that at this stage there has not been time to run a suite of sensitivity tests with both ENZ and C-PLAN in an integrated manner. This should be a priority for future research.

Other scenarios

The small changes in GDP for quite large changes in carbon prices may suggest that analysing lower cost ways to meet emissions reduction targets (eg NDCs) are almost pointless. Nevertheless if the actual rate of EV uptake falls substantially behind projections (perhaps limited by world supply) or the domestic carbon price increase is limited by political pressure, there may be a need to consider purchasing international emission units – given that an acceptable trading regime exists.

At this stage it is unclear whether C-PLAN can simulate such a scenario, but in time such a scenario would add robustness to the modelling results.

Another scenario to strengthen the envelop of modelling results would be to test the effects of major industry shocks – for example a widespread shift to synthetic protein, such that dairy and meat exports are markedly (say 80%) lower by 2050.

CSO questions

In relation to other questions raised in the CSO, the modelling system:

- Identifies potential emissions budgets.
- Determines whether the proposed emissions budgets are feasible technically, economically, socially – although the social impacts have yet to be presented.
- Determines whether the proposed emissions budgets are consistent with the targets for biogenic methane and all other gases.
- Identifies the macro and distributional, social and economic effects of the proposed emissions budgets; including by sectors such as agriculture and forestry – but again the social and distributional effects are yet to be released.

As to whether the modelling system is being used and maintained in a policy environment (rather than an academic or consultancy environment), one might propose that in an

academic environment a model is developed to be at the frontier of the field so as to produce some novel insights. In a consulting environment models are designed to answer the client's questions. That is also true here in a policy environment, the difference being that in the latter the one expects less protection of intellectual property. Indeed the RFP specifies that "The [Climate Change] Committee is not looking for proprietary economy-wide models." The models are still being finalised and documented, but at this stage the system looks on track to meet the RFP requirements.

Overall the models are sensible and have been used in a sensible manner. They are fit for purpose, albeit that 'purpose' may evolve over time.

Regarding Covid-19, the stance that the Commission has taken is entirely appropriate. Either Covid-19 (or some other virus induced disease) will be a non-issue over most of the period, or it will be so pervasive that it will warrant its own detailed modelling.

I am happy to discuss any aspect of the above especially if I've misunderstood something.

Yours faithfully

Adolf

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