# A CGE ANALYSIS FOR CLIMATE CHANGE NEGOTIATIONS: THE IMPACT OF ASSIGNED AMOUNT UNITS

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## Abstract

*Uncertainty surrounds the future of any international agreement on climate change. If an agreement similar to the Kyoto Protocol is negotiated, New Zealand will be responsible for all emissions above its Assigned Amount Units (AAU) allocation. This paper examines the macroeconomic impact on the New Zealand economy of changes in New Zealand's AAU allocation, using a computable general equilibrium model of the New Zealand economy. We find that at an emissions permit price of $NZ100/ton, an extra 15% AAUs on top of 1990 levels would increase welfare by around 0.7% and GDP by 0.2%.*

JEL Codes: C68, Q58

Keyword(s): CGE, climate change, New Zealand economy

## Introduction

The December 2009 United Nations Framework Convention on Climate Change meeting in Copenhagen made little progress in most areas. Uncertainty surrounds the future of any international agreement on climate change and New Zealand's amount of Assigned Amount Units (AAU). If an international agreement similar to the Kyoto Protocol is achieved, New Zealand will be responsible for all emissions above its AAU allocation. This paper examines the macroeconomic impact on the New Zealand economy of changes in New Zealand's allocation of AAUs, using a computable general equilibrium model of the New Zealand economy.

We do not compare possible mechanisms for domestic climate change policy such as an emissions trading scheme or carbon tax[2]. While the domestic policy settings are a matter for the New Zealand government, the amount of New Zealand's AAU allocation will be a result of international climate change negotiations. At least in the current debate, New Zealand's choice of domestic climate change policy mechanisms is divorced from the amount of AAU allocation it will receive.

We investigate the impact of changes in New Zealand's AAUs under the framework of an international agreement whereby New Zealand takes responsibility for any emissions above a given amount. This allows New Zealand to purchase emissions permits offshore if it is cheaper than reducing emissions domestically. New Zealand's domestic emissions can be greater than the AAU allocation, and thus our analysis is not analogous to investigating different domestic emissions targets: in our modelling framework, New Zealand does not care where emissions reductions come from and the decision to domestically reduce or purchase permits offshore is driven by the relative costs of permits and domestic abatement.

### The model

ORANI-NZ is a computable general equilibrium (CGE) model of the New Zealand economy. It is a New Zealand adaptation of the ORANI model; full documentation of ORANI is provided in Dixon et al (1982). ORANI-NZ models production of 210 commodities by 131 industries. The model is calibrated from 1996 input output data and 2003 supply and use data (Statistics New Zealand 2003). The model identifies three primary factors, labour, capital and land[3]. The model has one representative household and one central government. Optimising behaviour governs decision-making by firms and households. Each industry minimises unit costs subject to given input prices and a constant returns to scale (CRS) production function[4]. Household demands are modelled via a representative utility-maximising household[5]. Units of new industry-specific capital are cost minimising combinations of New Zealand and foreign commodities[6]. Imperfect substitutability between imported and domestic varieties of each commodity is modelled using the Armington CES assumption[7]. The export demand for any given New Zealand commodity is inversely related to its foreign-currency price[8]. The model recognises consumption of commodities by government[9], and the details of direct and indirect taxation instruments[10]. It is assumed that all sectors are competitive[11] and all markets clear[12]. Purchasers' prices differ from producer prices by the value of indirect taxes and trade and transport margins[13].

We augmented the standard ORANI-NZ model to include greenhouse gas accounting. It incorporates economy-wide emissions flows by fuel type, including combustion and non-combustion emissions; disaggregation of the electricity generation by fuel type; and the ability to introduce abatement at a cost to specific industries. Emissions data is sourced from the New Zealand Greenhouse Gas Inventory (Ministry for the Environment, 2009), and Statistics New Zealand Energy Usage statistics (Statistics New Zealand 2008).

**Simulation design**

We consider a long-run simulation out to 2020. We use a standard long-run model closure, exogenising the rate of return on capital and the investment/capital ratio, while endogenising capital stocks. Similarly, we set labour supply at long-run projection levels, and allow the real wage to fluctuate to achieve equilibrium in the labour market.

For consistency in comparing different AAU allocations, we fix a number of policy and technology responses: we assume New Zealand maintains an emissions trading scheme, and that there is no change in technology or forestry in response to changes in the price of emissions permits. We consider the implications of these assumptions in the discussion of results.

AAU allocations are a wealth transfer to the New Zealand government from the rest of the world. We model any extra government revenue derived from extra AAUs as being passed on to households via lower personal income taxes; similarly, a reduced amount of AAUs is funded via higher personal income taxes. The level of allocated AAUs does not alter New Zealand's domestic climate change policies.

Real gross national disposable income (GNDI) is our preferred measure of economic welfare. It measures the total incomes New Zealand residents receive from both domestic production and net income flows from the rest of the world (Statistics New Zealand, 1999), and adjusts for changes in the terms of trade. This is particularly pertinent for this analysis which includes offshore payment for excess emissions over our AAU allowance. GNDI includes these effects in contrast to the GDP metric which provides an indicator of domestic production but does not capture the impact of international transfers and investment income.

**Scenarios**

The baseline scenario we consider is essentially a continuation of the Kyoto protocol. New Zealand receives an AAU allocation amount equal to 1990 emissions levels (61.9Mt). Under business-as-usual (BAU) growth, net emissions are projected to reach 87.7 Mt by 2020[14]. This leaves a 2020 emissions deficit of 25.8Mt.

With an international agreement in place, any deficit can be met by reducing domestic emissions and/or purchasing additional emissions permits from other countries.

We consider three alternative scenarios to the baseline scenario: an AAU allocation of 37.1Mt (-40% of the 61.9Mt baseline), leaving a deficit of 50.6Mt; an allocation of 52.6Mt (-15%), leaving a deficit of 35.1Mt, and an allocation of 71.2Mt (+15%), leaving a deficit of 16.5Mt (Table 1).

The value of AAU allocations is dependent on the world emissions permit price. We consider primarily a world price of emissions permits of $NZ100/ton, and test the sensitivity of results to prices of $NZ25/ton and $NZ200/ton.

In Table 2, we present the relative costs and benefits of receiving more (in the case of the +15% scenario) or less (in the case of the -15% and -40% scenarios) AAU allocations at various emissions permit prices.

An extra 15% of AAU allocations are worth $NZ232 million on the world market at a price of $NZ25, and $NZ928 million at a price of $NZ100.

New Zealand's real GNDI is expected to be roughly around $NZ235 billion in 2020, so the value of changes to New Zealand's AAUs equates to around 0.1% of 2020 GNDI at an emissions permit price of $NZ25 and around 0.4% at an emissions permit price of $NZ100.

The "worst case" scenario of a 40% reduction in AAU allocations at a world price of $NZ200 is worth almost $NZ5 billion on the world market, or 2.1% of 2020 GNDI.

**Results**

Table 3 provides the key 2020 macroeconomic results. At an emissions permit price of $NZ100/ton, an amount of AAUs equal to 1990 emissions levels results in a -2.4% deviation in real GDP and a -2.3% deviation in real GNDI, versus a BAU baseline. This is not to say the New Zealand economy has contracted, but that it is smaller than it otherwise might have been. This result provides the reference point for changes in New Zealand's allocation of AAUs.

If international climate change negotiations were to provide New Zealand an extra 15% of AAUs, the deviations in real GDP and GNDI fall to -2.3% and -1.6% respectively. Conversely, if New Zealand negotiates for 15% less AAUs, the deviation would increase to -2.6% in real GDP and -3.0% in real GNDI. At an AAU allocation amount 40% less than 1990 emissions levels, the deviation in real GDP and GNDI drops further again to -2.9% and -4.2%.

The results suggest an effective elasticity between real GNDI and changes to AAUs from 1990 emissions levels of around 0.05. That is, an increase in AAUs over and above 1990 emissions levels of 1% would be expected to benefit long term real GNDI by 0.05%.

Table 4 shows the real GNDI results for the scenarios under different world prices of emissions permits. With AAU allocations at 1990 emissions levels, the deviation in real GNDI at an emissions permit price of $NZ200/ton is -2.8%. This contraction is more severe (-6.6%) under the worse case scenario of a 40% reduction in the amount of AAUs. The effective elasticity increases to around 0.1.

## Discussion

Tightening New Zealand's AAU allocation is like the rest of the world deciding that our balance of payments deficit is too large and must be reduced. This requires more of the country's resources to flow into exporting and out of domestic consumption, which lowers imports and thus also helps to improve the balance of payments.

The necessary shift in the allocation of resources is induced by a devaluation of the exchange rate. A devaluation makes us poorer in terms of national income even if there is no change to the national volume of production – real Gross Domestic Product (GDP). One New Zealand dollar of exports buys fewer imports than before the devaluation. Therefore, to purchase an extra AAU, costing for example one foreign dollar, more than one New Zealand dollar's worth of exports is required, further reducing the resources available for domestic consumption.

More intuitively perhaps, for a given level of output, we cannot expect to maintain our standard of living if we have to transfer more of that output offshore. Hence as New Zealand's AAU allowance is changed we expect to see a larger effect on real Gross National Disposable Income (GNDI) than on real GDP.

Finally, the amount of AAUs allocated to New Zealand does not directly alter the price of emissions permits that New Zealand firms face[15]. This means that the level of AAUs does not directly impact on the level of production of New Zealand firms. Given that GDP is a measure of New Zealand firm production, changes in the allocation of AAUs do not directly impact New Zealand GDP. Similarly, the changes in allocations of AAUs do not directly impact domestic emissions reductions.

### Forestry

We noted in the simulation design that our models do not capture the response of forestry to a price on emissions. While even a low carbon price is likely to change incentives for land use, uncertainty over long term policy and regulation environments, as well as factor and liquidity constraints make the relationship difficult to estimate.

The Ministry for Agriculture and Forestry (MAF) (2009) suggest that, assuming long term policy certainty, a $NZ20 emissions permit price could theoretically induce up to 100,000 hectares of new planting per year up to 2020, and prolong rotation lengths. Collectively, this would increase New Zealand's emissions sequestration by up to 30Mt in 2020 (although emissions would increase at a later date if/when the forests are harvested).

The implications of such a forestry response are substantial. Table 1 shows an expected emissions deficit of 25.8Mt in 2020 under 1990 levels of AAUs. An extra 30Mt of forestry sequestration would turn New Zealand's 25.8 Mt emissions deficit into a 4.2Mt emissions surplus. Effectively, an increase in carbon sequestration is equivalent to an increase in allocation of AAUs. Thus we would expect real GDNI to benefit significantly (as New Zealand becomes wealthier). However because firms still face a price on emissions, GDP would be largely unaffected.

If the forestry response to even higher emissions permit prices is consistent with those suggested by MAF above, carbon sequestration could offset the negative wealth effect of stringent AAU allocations by eliminating the need to purchase emissions permits from other countries.

## Conclusions

International climate change negotiations will determine the amount of AAUs New Zealand receives. We wish to be seen to 'doing our bit' however there is a cost to foregoing AAUs. In all tested scenarios, while reducing domestic emissions, New Zealand still has an emissions deficit – meaning that we must purchase emissions permits from offshore.

The fewer AAUs that New Zealand is allocated, the larger is our emissions deficit and the number of emissions permits we need to purchase to meet our international obligations. Buying these permits to fund our emissions deficit comes at a cost. Additional resources are directed towards exporting, making fewer available for household consumption.

This suggests that New Zealand's negotiators should continue to be pragmatic in future international climate change discussions: adopting a tougher target is not costless.

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**Table 1. AAU allocation and emissions deficit (Mt $CO_2$-e)**

| | AAU percent change versus 1990 | | | |
|---|---|---|---|---|
| | **-40%** | **-15%** | **0%** | **+15%** |
| AAUs | 37.1 | 52.6 | 61.9 | 71.2 |
| Baseline 2020 emissions | 87.7 | 87.7 | 87.7 | 87.7 |
| Emissions deficit | -50.6 | -35.1 | -25.8 | -16.5 |

**Table 2. Value of changes to New Zealand's AAU allocation ($NZ million)**

| | AAU percent change versus 1990 | | | |
|---|---|---|---|---|
| **World price $NZ/ton** | **-40%** | **-15%** | **0%** | **+15%** |
| $25 | -619 | -232 | 0 | 232 |
| $100 | -2,476 | -928 | 0 | 928 |
| $200 | -4,952 | -1,856 | 0 | 1,856 |

**Table 3. 2020 macroeconomic impacts of changes to New Zealand's AAU allocation at emissions permit price of $NZ100/ton (percentage deviation versus baseline)**

| | AAU percent change versus 1990 | | | |
|---|---|---|---|---|
| | **-40%** | **-15%** | **0%** | **+15%** |
| Real GDP | -2.9% | -2.6% | -2.4% | -2.3% |
| Real GNDI | -4.2% | -3.0% | -2.3% | -1.6% |
| Real wages | -10.4% | -9.8% | -9.4% | -9.0% |
| Private consumption | -4.5% | -3.2% | -2.4% | -1.6% |
| Domestic emissions | -17.1% | -17.5% | -17.7% | -18.0% |

**Table 4. 2020 real GNDI impact (percentage deviation versus baseline)**

| | AAU percent change versus 1990 | | | |
|---|---|---|---|---|
| **World price $NZ/ton** | **-40%** | **-15%** | **0%** | **+15%** |
| $25 | -1.1% | -0.9% | -0.7% | -0.6% |
| $100 | -4.2% | -3.0% | -2.3% | -1.6% |
| $200 | -6.6% | -4.2% | -2.8% | -1.8% |

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[2] See Infometrics and NZIER (2009)

[3] Capital and land are specific to each industry. Labour is occupation-specific, but free to move between industries.

[4] The 131 industry-specific production functions are nested constant returns to scale. The top level of the nested production functions are fixed proportions in 210 composite commodities and a primary factor composite. Each of the 210 x 131 composite commodities is a CES (constant elasticity of substitution) composite of source-specific varieties of the commodity. Two commodity sources are identified: New Zealand and foreign. The primary factor composite is a CES composite of land, labour and capital. The model thus has 55,413 (= 210 x 131 x 2 + 131 x 3) cost-minimising input demand functions over source-specific commodities and primary factor inputs. See Dixon *et al.* (1982: 76-90).

[5] The representative household maximises a Klein-Rubin or Stone-Geary utility function in current-year consumption of 210 composite commodities subject to current-year income. Each of the 210 composite commodities is a cost-minimising CES (constant elasticity of substitution) composite of source-specific varieties of the commodity. Two commodity sources are identified: New Zealand and foreign. The household optimisation problem thus produces 420 ( = 210 x 2) utility maximising demand functions over source-specific commodities. See Dixon *et al.* (1982: 96-103).

[6] Units of new industry-specific capital are produced via industry-specific nested constant returns to scale production functions. The top level of the nested production functions are fixed proportions in 210 composite commodities. Each commodity composite is in turn a cost-minimising CES (constant elasticity of substitution) composite of source-specific varieties of the commodity. Two commodity sources are identified: New Zealand and foreign. The model thus has 55,020 (= 131 x 210 x 2) cost-minimising demand equations relating to inputs to capital formation. See Dixon *et al.* (1982: 94-96).

[7] That is, each of the 210 commodity composites demanded by each of the model's agents is a cost-minimising CES (constant elasticity of substitution) composite of imported and domestic varieties of the commodity. See Dixon *et al.* (1982: 69).

[8] Commodity-specific export demand functions are constant elasticity of demand. See Dixon *et al.* (1982: 104-105).

[9] With 210 commodities and two sources of supply, the model recognises 420 source-specific government commodity demands. These demands are modelled as either exogenous or indexed to aggregate public consumption spending. See Dixon *et al.* (1982: 105).

[10] Direct taxes are levied on labour and capital income. Indirect taxes are potentially payable on every source-specific commodity flow to each agent (=210*2*(131+131+1+1) indirect taxes), production by industry (=131 indirect taxes), imports by commodity (=210 indirect taxes), and exports by commodity (= 210 indirect taxes). However, indirect taxes on most sales are zero. Given New Zealand's VAT system, the bulk of the indirect tax burden falls on commodity-specific flows to household consumption. See Dixon *et al.* (1982: 108-117).

[11] We calculate the average unit cost of production for each of the model's 131 industries. Given the constant returns to scale technology that characterises each industry's production function, the average unit cost is also the marginal cost. The competitive zero pure profits condition that output price is equal to marginal cost is enforced via an assumption that the average cost of each industry's output is equal to the average price received on the commodities sold by each industry. See Dixon *et al.* (1982: 108-110).

[12] In both the short-run and long-run, imports are available in elastic supply at given world prices. Short-run market clearing is imposed on sales of domestic commodities and industry-specific physical capital markets. As discussed in Section 2.1, short-run labour markets are characterised by stickiness of the real consumer wage (see Dixon and Rimmer 2002: 204-210). Long-run market clearing is imposed on all markets other than commodity-specific import markets, where again, import supply is assumed to be elastic at given world prices. See Dixon *et al.* (1982: 122-125).

[13] Five types of margin are modelled: wholesale trade, retail trade, road freight, other road transport services, and rail and sea transport services. In the absence of exogenous movements in technical change, demands for margin services are assumed to be a fixed proportion of the physical commodity flows that they facilitate. See Dixon *et al.* (1982: 106-108).

[14] This was correct as of July 2009 when the analysis was completed, based on emissions projections from the Ministry for the Environment. There has been considerable variation in New Zealand's projected 2020 emissions since then, however the key results still stand, and can be applied to new emissions projections as they are updated.

[15] If connected to an international trading agreement, New Zealand will be price takers of the world price of emissions permits. If not connected, the price will be a result of the targets set by the New Zealand government for domestic emissions reduction.