Analysing the impacts of the net zero-emission policy on New Zealand’s carbon trading and land use

Abstract

In this paper, we investigate the impact of net zero-emission policy on New Zealand’s macroeconomy, including carbon permit pricing and land use change under two scenarios. Both scenarios base on domestic forestry being the only source of permits and assume net zero emission. One scenario includes agriculture whereas another excludes this domestic largest emission contributor. We developed an integrated model, forest-CGE, to derive an equilibrium carbon permit price subject to an endogenous forest rotation age. Various mechanism of carbon permit allocation is also considered. Our results estimate an equilibrium carbon permit price of NZ$81 and NZ$74 per tonne carbon dioxide equivalent in each scenario respectively to meet the zero net emission target by 2050. Also, it shows that the New Zealand Emissions Trading Scheme with agriculture included contributes to a 14% reduction in the nation’s total emissions, approximately half of New Zealand’s 2030 goal. The forestry sector increases by 75% and 57% of land use coming from other sectors in each scenario. The GDP declines due to reduced production in most sectors with emerging emission cost, leading to decreased exports. Household income is negatively affected by decreased factor price but compensated by providing renewable resources. Whether including agriculture in the existing emissions trading scheme generates a different impact on the macro-economy.

Key words: carbon price, land use, CGE, NZ ETS, and forestry.

JEL classification: Q23; Q24; Q54; Q68

1. Introduction

Considering to contribute its efforts to alleviating the global climate change pressure, New Zealand (NZ) introduced a market-based carbon emissions trading scheme (NZ ETS) since 2008. It was the first national emissions regulation regime in the world that covered all the sectors of the economy and the six major greenhouse gases (GHG). The ETS has several unique features that reveal the speciality of the economy. For instance, unlike most of the developed economies, the most significant emission sources in NZ are methane and nitrous oxygen from agricultural activities by 49% instead of energy consumption. At the initial step of the ETS proposal, the government considered to include agricultural sectors into the scheme. However, this regulation would increase production cost to farmers which damage the productivity of the primary industry in New Zealand. In 2012, the government decided to withdraw the agricultural sectors from the ETS regulation forever. But farmers can still be the individual volunteer to report emission, and they can trade carbon permits in the international carbon market. Besides, the traditional emission sectors - transport contribute to the second most substantial emissions profile by 40% (Ministry for the Environment, 2018). The primary energy consumed in the transport sector sourced from liquid fuel, which provides 75% of the transport sector's emissions. However, there is a very high proportion of renewable energy use domestically about >80% in the electricity generation sector. Agriculture is the largest producer of GHG emissions and forestry represents a major carbon sink sector which contributed 23,836 Gg carbon dioxide equivalent (CO_2-e) sequestration in 2007. At the latest global convention on climate change (COP21), held in Paris at the end of 2015, participants agreed on a global treaty of reducing emissions aimed at limiting the rise of global warming. NZ government announced a target aimed at reducing domestic GHG emissions to 30% below the 2005 level by 2030.

The total land area in NZ is 268,021 square meters with 30% of natural forest and over half of the grassland that mainly used in agricultural sectors. Other types of land such as cropland and scrubland take up 2% and 4% of total land area, respectively. The rest of the land types includes lakes, settlements, and wetland is accounted as 13% of the national land hectares in 2008 (Ministry for the Environment, 2010). It has been a long time that forestry is a large sector; however, driven by profitability in dairy farming, large areas of forest land converted to dairy use which in turn increased the GHG emissions. By considering the environmental and economic impact due to the climate change, NZ government issued some land-related Acts such as the Resource Management Act (RMA) and the Exclusive Economic Zone (EEZ) to set up a guideline for sustainable land use in a long run (Carter, 2019). If emissions from agricultural sectors are included in the NZ ETS, it will generate a great change in land use pattern between the two primary industries.

A conventional ETS was limiting the number of total emissions by setting a cap (e.g., EU ETS and China ETS). However, NZ ETS does not have any national cap on emissions but under the Kyoto Protocol regulation (Leining & Kerr, 2016). As aforementioned, the NZ ETS is market-based where the market would put a price on emissions. This mechanism enables participants to buy and sell carbon permits based on their own profit maximisation choice. The price control is more efficient than the quantity control (e.g. cap-and-trade) given the emissions reduction target, due to absent of information on the cost of emission reductions and competitiveness loss to the economy (Ermolieva et al., 2010; Tietenberg & Lewis, 2016; Weitzman, 1974). The forestry is functional of absorbing carbon emissions so that it could generate the offset credits. However, it is not clear how long the temporary carbon sequestration could protect the carbon emissions from the atmosphere (Kooten, 2009). Thus, it is crucial to ensure the amount of carbon sequestration in a certain period before harvest. The carbon stock associated with the forestry sector is estimated as a function of the net change in forest area, age, and a pickle factor that accounts for the carbon in the wood that has been harvested (Gardiner, 2009; Hertel et al., 2009; Lubowski et al., 2006; Sohngen et al., 2008). Optimal forest rotation age is determined by growth rate, carbon sequestration during the growth cycle, the value of harvested timber and carbon price up to and including the time of harvest (Hartman, 1976).

Some of the computable general equilibrium models (CGE) used an exogenous carbon permit price to evaluate the impact on the economy (Informetrics, 2007; NZIER, 2008), and few of other studies investigate an abatement cost for each sector. For instance, Diukanova and Andrew (2008) found that agricultural output is reduced given an emissions abatement cost of NZ$13.2 per tonne CO_2-e. However, few CGE studies within the NZ context spot on the calibration of an equilibrium carbon price and associated impacts considering endogenous forestry. There is a dynamic CGE model developed to examine the response of NZ to domestic and international climate change policy, i.e. CliMAT-DGE (Fernandez & Daigneault, 2015). This model forecasts a series output including GDP, carbon emissions, production, welfare, and so on at multi-regional and multi-sector scope until 2100. However, this model treats the global carbon market as a single market where each household can export or import from other regions. Thus, it does not consider how NZ specific permit – NZU work within NZ's own carbon trading market.

It is essential and timely to study the economic impacts of the NZ ETS on carbon trade and land use. Firstly, NZ is the first single country who implemented the domestic climate policy that would shed light to other countries, especially those who has a large share of agriculture in their economies. Secondly, by discussing the pro and con of the current policy, it would generate key policy implications to NZ policy maker to achieve the national emission reduction target efficiently. This paper will address two questions: first, how much of carbon credit price will be if agricultural emission is involved in the trading scheme; then, what is an impact of the ETS on macro-economy, and land use change between the two significant sectors.

The rest of the article is organised as follows. Section 2 describes the structure of the forest-CGE model. We then introduce two scenarios: first, an S1 scenario that includes agriculture sector and forestry is the only source of carbon permits; second, an alternative "S2" where agriculture is excluded the existing scheme. We also change the mechanism of permits allocation in the model to compare the economic outputs. In section 3, we present the critical results including the carbon price, land use change, and the impact of the ETS on the economy. Section 4 concludes and provides critical policy implications.

2. Model Structure

In this section, we first introduce the model and then the scenarios used for simulation. The forest-CGE model is static with 16 aggregated sectors and 15 commodities spanning the economy based on the Australian and New Zealand standard industrial classification (ANZSIC) standard (Stats NZ, 2006). The 16 sectors include forestry, stationary energy, industrial processes, synthetic gases, waste, horticulture and fruit growing, sheep, beef cattle and grain farming, dairy cattle farming[1], other agriculture, forestry manufacturing, agriculture manufacturing, retail and wholesale trade, manufacturing, non-renewable electricity, renewable electricity, and service.

A nested production structure characterises all sectors as seen in Figure 1. Domestic production is based on the Leontief function, incorporating aggregated intermediate (INT in figure 1), carbon credit, and value-added inputs (VAL). Domestic and foreign goods are components of intermediate use; primary factors, such as labour, capital, and composite land, are value-added

[1] Sectors "horticulture and fruit growing", "sheep, beef cattle and grain farming", and "dairy cattle farming" are written as "horticulture", "sheep-beef", and "dairy farming" in later sections.

inputs. We assume the composite land incorporates five types of land (forest, grass, crop, scrub, and other) with substitution other across five sectors: forestry, horticulture, sheep-beef, dairy farming, and other agriculture. The nesting structure of land use among sectors is shown in figure 2. The elasticities of substitution between each type of land are drawn from Rae and Strutt (2011) and Rutherford (2003). Land use areas were obtained by merging geographic (LCDB V2) and industrial use data (provided by Agribase dataset).

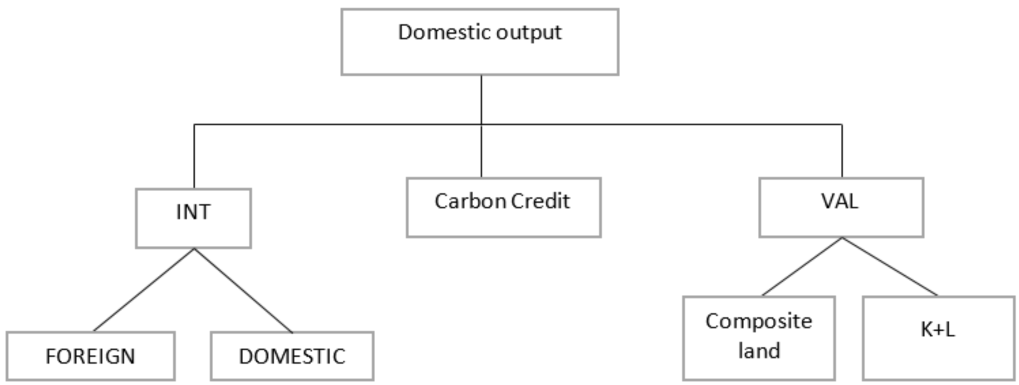

Figure 1. Nesting structure for the production sector

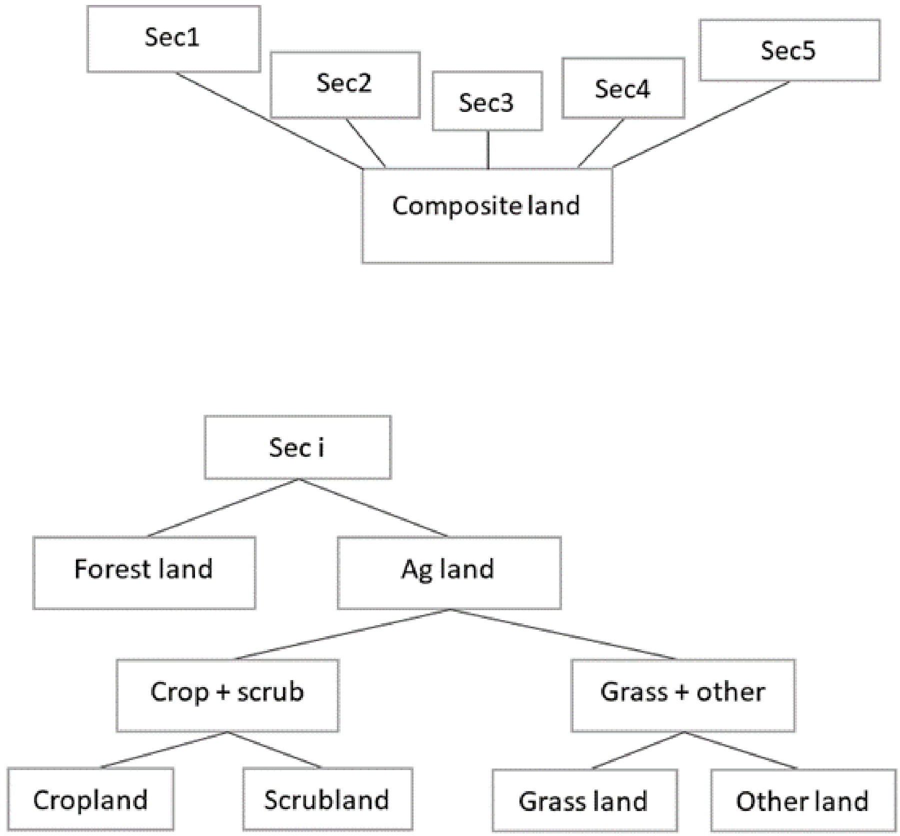

Figure 2. (Up) Land allocation among sectors; (Down) Land use within each industry

The electricity sector is disaggregated into non-renewable and renewable sources of energy. The non-renewable sector uses coal, oil, and gas as intermediate inputs, whereas the renewable electricity sector uses three types of renewable resources: geothermal, wind, and hydro. Domestic goods are transformed to exported goods according to a constant elasticity of transformation (CET) function.

In the commodity market, both imported goods and domestic production are sold in the domestic market. Imported and domestic products are heterogeneous and are not perfect substitutes. The Armington function is used to depict substitution.

CO2-e measures GHG emissions. Carbon permits can only be traded in the domestic carbon market. Two scenarios are examined: (1) S1 policy, including agriculture in the existing scheme, and all carbon permits source from forestry; (2) S2 policy, excluding agriculture sectors. All other sectors still buy carbon permits to cover the sectoral carbon emissions. The nexus of buying and selling carbon permits is by one unit of credit equals one tonne of CO_2-e emission. In both scenarios, forest owners supply permits to the market but face liability at deforestation. An equilibrium carbon permit price is determined by equalising the supply and demand for permits.

An optimal rotation age of post-1989 radiata pine under a “pruned, without production, thinning” regime is estimated from a partial equilibrium forest model by maximizing net present value (NPV) from three paths: timber sales, carbon sequestration, and carbon emission liability payment (Kooten et al., 1995; Sands & Kim, 2008). It is assumed that forestry is in a steady-state, implying that forestry profits are equalised each year from planting to optimal rotation age. Harvesting and replanting costs which include land transition costs are endogenous in the model.

Linking the forest model to CGE is a significant contribution made by this paper. The forest growth model is partial equilibrium, calibrating an optimal rotation age and timer yield by maximising forest owner’s NPV including tree planting and carbon sequestration. The CGE model looks at a variety of economic output such as GDP, land use and carbon price. At this optimal rotation age, we first calculate a change in carbon sequestration through the shift in timber yield at equilibrium level (see equation 1 and 2), then re-calibrate a new carbon sequestration level by the forestry production determined by the CGE model. By doing so, we can obtain the carbon credit supply which equalises to credit demand when both forest and the CGE model reach equilibrium.

$$\frac{y_t^o}{y_t^b} * C_s^b = C_s' \quad (1)$$

$$C_s' * y_t^e = C_s^e \quad (2)$$

Where y_t^o represents timber yield from the partial equilibrium forest model; y_t^b is the timber yield at baseline. C_s^b is carbon sequestration amount at baseline. y_t^e shows the timber production determined by the CGE model, and C_s^e is the carbon sequestration at an equilibrium level.

Furthermore, both commodity and factor markets clear. Factor endowments are fixed. Capital is immobile internationally but can move freely in NZ. Investment is fixed, and savings are endogenous in the model. Foreign saving (FSAV) is determined by the model for balancing the international trade account.

2.1 Scenarios

The economy is constrained by a carbon market based entirely on forest sequestration. Total carbon sequestration from forestry equals total carbon emissions. In both the scenarios, S1 and S2, growing trees are the sole source of carbon credits. The only difference between these two scenarios lies in that, whether the agriculture emissions are accounted in the existing scheme. We use CO2-e to measure all the carbon emissions in both scenarios. These assumptions aim to better reflect the economic sector's response to "zero-net-emission vision" given the agriculture sector is the largest emission source.

Moreover, we change the mechanism of supply-demand of permits from "one permit equals to one ton of emission" to "one permit equals to two tons of emission" and "one permit equals to three tons of emissions". By examining this scenario, we can obtain insight on how agricultural sectors decide different ETS regime, the magnitude of the carbon price range, and the impact on the macro-economic indicators.

2.2 Baseline and data

The social accounting matrix is based on the 2007 supply-use table, the latest available. We extend it to incorporate renewable energy use and land use by sectors. To better reflect the current economy, we scale up the 2007 year's data to the 2016 level and set the 2016 economy as the baseline. The Ministry for the Environment (MFE) reports the CO_2-e emission data by sector and source (Ministry for the environment, 2009). Total GHG emissions in 2007 were 75.6 Tg CO_2-e. A negative sign is attached to carbon sequestration shown in Table 1.

The total agriculture sector contributed 36.4 Tg CO_2-e emissions, which was 48.2% of the total emissions. Because of limited data on horticulture emissions, we assume that emissions for this sector come from direct and indirect nitrogen loss from agricultural soils, and the use of nitrogenous fertilizer. Under the agriculture soil category, direct N_2O soil emissions contribute 1.7 Tg CO_2-e, and indirect N_2O from nitrogen used emits 3.3 Tg. Total emissions form horticulture and fruit growing sector are calculated by summing up the data.

The timber growth follows the ETS regulation, and we chose two dominant trees in NZ. That is, radiate pine and douglas fir for post-1989 planting across 12 regions (Auckland, Canterbury, Central-north island, East-coast, Hawkesbay, Marlborough, Nelson, Northland, Otago, Southern-north island-east coast, Southern-north island-west coast, and Southland). The post-1989 trees cover the forest planted since 1990, and the timer yield data is used from the Ministry for Primary Industries (2011). Due to the unevenness of forestry distribution in NZ, we calculated the weighted ratio of each planting area to the national planting area to differentiate the planting volume of the trees. What's more, to obtain the land use by sectors in a hectare, we merged the spatial land distribution into industrial use data running in ArcGIS.

3. Results

3.1 Carbon price and sectoral emissions

An equilibrium carbon price is estimated at NZ$81.4 per ton of CO_2-e in scenario 1 including agriculture and NZ$74.3 per ton in scenario 2 excluding agriculture. The purpose of setting these two scenarios is to compare the economic impact of the ETS with and without the largest domestic emissions contributor – agriculture. To meet the zero net emission goal, the emission-intensive sector's output dropped whereas forestry and its related industry expand production. Table 1 shows the variance of sectoral emission level compared to the baseline at policy compliance cost $81.4/t and $74.3/t of CO_2-e each.

Table 1. Change in sectoral emissions (% relative to baseline)

Sector	**Including agriculture**	**Excluding agriculture**
Stationary energy	-1.7%	-2.1%
Industrial processes	3.8%	3.1%
Synthetic gases	-10.7%	-9.6%
Waste	-23.9%	-23.0%
Horticulture and fruit growing	-21.5%	0
Sheep-beef cattle and grain farming	-39.3%	0
Dairy cattle farming	-36.9%	0
Other agriculture	-30.3%	0
Forestry manufacturing	17.6%	14.1%
Agriculture manufacturing	-34.8%	-25.9%
Retail and wholesale trade	0.5%	0.4%
Manufacturing	2.0%	1.7%
Non-renewable electricity	-12.6%	-12.0%
Renewable electricity	0.0%	-0.1%
Service	1.6%	0.9%
Total gross emissions	-14%	-1.5%
Net emissions	0	0

From the above table, it shows a declining change in most sectoral emissions, especially for agricultural sectors. At the emerging carbon emission cost, agriculture sectors reduce its emission level significantly among all sectors if they are included in the scheme, followed by energy and waste sector. As a result, the total gross emissions drop by 14%. However, if agriculture is excluded in the scheme, the gross emission reduced by 1.5% only. Also, most of the sectoral outputs decrease whereas forestry and its associated industry increase output when carbon price occurs. Due to the assumption of free movement of labour and capital, the production factors can move to industries with smaller emission cost such as service. The variety of sectoral output is not significant in most sectors under two scenarios.

3.2 Land use change at emission cost

To differentiate forest land from other types of land, we set a low elasticity at 1.5 for other lands converting to forest land, and a high elasticity of 20 which makes land conversion much easier with agricultural sectors than with forestry. This high elasticity of substitution is drawn from Rae and Strutt (2011). Low elasticity drives an increase in forest land for sector use.

With agriculture included in the scheme, the equilibrium carbon price of $81.4 would motivate obtaining and selling carbon permits. Two main factors affect land use among sectors: sectoral output; and, the elasticity of substitution among the land. Increasing output leads to a rising demand for production factors such as land, labour, and capital. If the elasticity of substitution is low between two types of land, e.g. forest land and other land, then it reduces the ease with which other land can be converted to forestry use. Again, in this paper, we set a low elasticity of substitution between forest land and other four types of land, which makes forest land relatively expensive. Table 2 illustrates the land use change in hectare between forestry and agriculture sectors at the compliance cost. A clear trade-off between forestry and agricultural sectors shows that pricing carbon is beneficial to the forestry sector, but is a production cost to agriculture. Between both scenarios, the effect of an equilibrium carbon price on sectoral land use is almost the same except for horticulture due to the difference in emission data.

Table 2. Percentage change in a hectare (% of baseline)

S1	**Forest land**	**Other land**	**Grassland**	**Scrubland**	**Cropland**
Forestry	76.9%	67.8%	69.5%	60.1%	67.7%
Horticulture	-70.6%	6.1%	7.3%	1.3%	6.1%
Sheep-beef	-72.5%	-1.2%	-0.1%	-5.7%	-1.2%
Dairy farming	-73.2%	-3.9%	-2.9%	-8.3%	-4.0%
Other agriculture	-72.5%	-1.0%	0.0%	-5.5%	-1.1%

S2	**Forest land**	**Other land**	**Grassland**	**Scrubland**	**Cropland**
Forestry	63.9%	21.5%	22.5%	19.7%	22.6%
Horticulture	-60.9%	-2.6%	-1.8%	-3.9%	-1.6%
Sheep-beef	-60.0%	-0.1%	0.7%	-1.5%	0.9%
Dairy farming	-61.8%	-4.9%	-4.1%	-6.3%	-4.0%
Other agriculture	-62.2%	-5.7%	-4.9%	-7.0%	-11.4%

3.3 Impact of compliance cost on forestry variables

We assume forest owner maximises NPV overall future periods (NPV4) by three paths: timber sales (NPV1), carbon sequestration (NPV2), and emission liability (NPV3). With an assumed interest rate of 4%, the equilibrium rotation age is around 29 years across all scenarios. Timber price decreases from baseline NZ$88 to NZ$87.7 in all situations. This result is partly due to profits derived from selling carbon permits, and increased terms of trade (around 1% under both scenarios) relevant to the baseline, leading to a rise in timber production. Results for forest variables across the three scenarios are shown in Table 3.

Table 3: Forest variables results (per hectare)

Variables	S1	S2
Rotation age	29	28
Timber yield	617	604
Timber price	87.7	87.6
NPV1	17265.6	17098.0
NPV2	16482.8	14807.2
NPV3	-11220.0	-10160.0
NPV4	33084.2	32149.4

Although we set a low discount rate of 4% for forest owner, the forest owner can still obtain profits from selling timbers as seen in the NPV1. A higher carbon price pushes up demand for planting trees and supplying carbon permits, leading to a rise in NPV2 in the S1 scenario (including agriculture) than S2 (excluding agriculture). Accordingly, the rising NPV3 in the S1 scenario implies higher emissions liability due to higher timber production.

3.4 Impact of the compliance cost on economic variables

Brought by the emission cost, the ETS would generate a negative impact on GDP and employment. Decreased output shrinks the total domestic product, whereas the magnitude is merely small shown in this study. Labour and capital price would drop as well due to the lower production. However, in equilibrium, we allow factor to free move among sectors. Thus, factors from the emissions-intensive industry would move to a less polluted industry.

Given that NZ has regulation on domestic sectors whereas the foreign economies are not assumed to have the same rule. Hence, the local input used for production is relatively expensive than imported, due to the elasticity of substitution between these two inputs. Consequently, the terms of trade would decline as well, which increases the export.

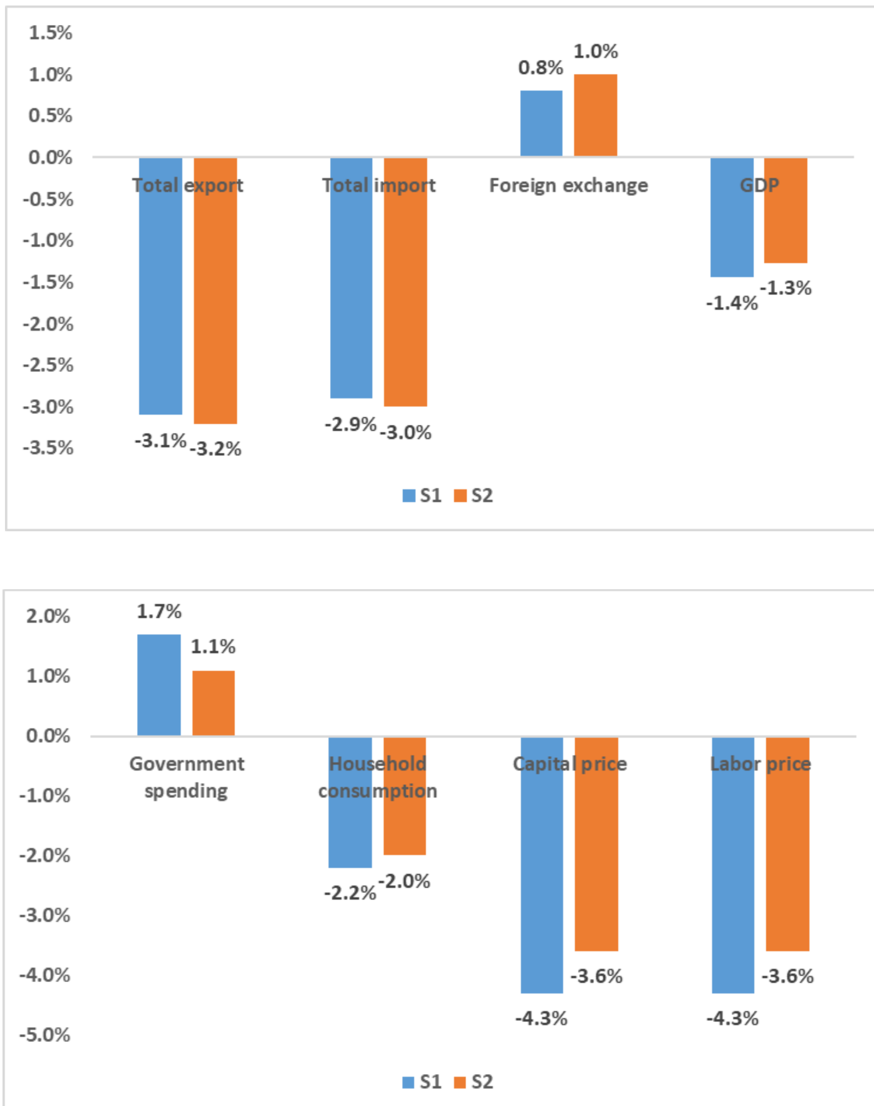

Figure 3. Change of macroeconomic variables in both scenarios

As shown in Figure 3, real GDP declines by 1.4% and 1.3% for each scenario. This effect can be explained by decreased sectoral output. The reduction of the sectoral production leads to an increase in domestic commodity prices, which makes domestic supply relatively expensive to imported goods. Therefore, imports increase in both scenarios. The increased foreign exchange rate implies a relative expensive in New Zealand exported products, lowering exports.

The reduction in sectoral output decreases the demand for factor used in most sectors except for forestry and its related sectors. Overall, the price of labour and capital decrease, leading to a decline in household consumption in both scenarios. Instead, given a rising income coming from less emission-intensive sectors and renewable resources, the tax payment goes up. As a result, government consumption increases by 1.7% and 1.1% under the S1 and S2 scenario, respectively.

3.5 Additional scenario

Both scenarios based on the permit trading principal "one unit emission permit equals one tonne of carbon emission". In this section, we conduct additional scenarios including changing the nexus of permits supply and demand. That is, we assume 2 tonnes of emissions can be traded with 1 unit of permit.

Under this assumption, the carbon permit becomes a scarcity. With the agriculture included, an equilibrium carbon price rises to NZ$150/tonne CO_2-e emission. The total gross emission level decreased by almost 18%. Agricultural sectors suffer the most loss in production whereas forestry expands its output by almost five times at the high permit price. Forestry adopts over 91.4% of land from all the agriculture sectors. However, within the agriculture sector, more than 10% of grassland and cropland tend to horticulture use. This result is driven by substitution between horticulture and forestry, in other words, a relative cheaper conversion cost.

4. Discussion and conclusion

Unlike the previous studies, our research is the first try to have an endogenous forest sector and link it to a static CGE model within New Zealand's context. We emphasise the interaction of carbon sequestration from forestry to other economic sectors and let the integrated model examine the difference between having and not having agriculture sectors in the carbon trading scheme. From this study, we would like to highlight some vital information.

First, it is essential to have agriculture in the current ETS to meet the zero carbon vision. Agricultural sectors occupy almost half of national GHG emissions, excluded it implies a low demand for carbon permits in the carbon market. As a result, a low carbon permit price cannot generate motivation of afforestation, which in turn further increases carbon emission from agriculture and energy sectors;

Second, we estimate an equilibrium carbon price of NZ$81.4 and NZ$74.3 per tonne of CO_2-e emission based on the 2016 NZ's economy. The cost goes up when the nexus of permit supply and demand shrinks. At this policy compliance cost, most sectors reduce their production leading to a fall in the real GDP. Domestic intermediate becomes expensive relevant to foreign goods under the carbon emission cost. As a result, the exported value also goes down due to the appreciated NZ dollar brought by the weakened competitiveness.

Under the zero net emission constraint, our results show that the ETS contributes to a 14% reduction in total emissions if allowing agriculture to enter the scheme. This reduction of emissions is about half of NZ's emissions reduction target in 2030 (30% below 2005 levels). However, without agriculture, the total gross emissions reduce by 1.5% only. It is clear to see the importance of having agriculture emissions in the market.

The design of ETS impacts to land use significantly. There is a clear trade-off of land use change between forestry and agriculture sectors when the compliance cost occurs. We find the carbon price change in both scenarios is significant when the allocation mechanism differs, implying the price is variant concerning the design of the ETS. Agriculture production decreases in both scenarios because of the carbon emission cost. Retail, renewable electricity, and service sectors are not very sensitive to the change in the carbon price. At the baseline, retail and renewable sectors do not generate many emissions. With a carbon price, the mobility of factors among sectors leads to an increase in production and emissions in the low emissions sectors such as service.

The main contribution of this study is considering carbon sequestration from an endogenous forestry sector within NZ's context. Most studies use a fixed carbon price (i.e. carbon tax) because it is relatively easier for model calibration. Regarding future research, we will investigate an optimal carbon permit price concerning a global carbon market. Besides, we will compare the NZ ETS and potential carbon tax, and highlight which policy performs better for the NZ economy in terms of macro-economic variables such as GDP, international trade, and carbon emissions reduction.

Reference

Carter, L. (2019). *Indigenous Pacific Approached to Climate Change* Switzerland: Spring Nature Switzerland AG.

Diukanova, O., & Andrew, R. L., James. (2008). *Emission Trading in New Zealand: Computable General Equilibrium Model and Evaluation*. Landcare Research.

Ermolieva, T., Ermoliev, Y., Fischer, G., Jonas, M., Makowski, M., & Wagner, F. (2010). Carbon emission trading and carbon taxes under uncertainties. *Climatic Change, 103*(2010), 277-289.

Fernandez, M., & Daigneault, A. (2015). *The Climate Mitigation, Adaptation and Trade in Dynamic General Equilibrium (CliMAT-DGE) Model*.

Gardiner, K. (2009). *Responsiveness of the Optimal Rotation of Pinus Radiata Forests to New Zealand Unit Prices.* (Master), the University of Auckland, Auckland, New Zealand.

Hartman, R. (1976). The Harvesting Decision When a Standing Forest Has Value. *Economic Inquiry, 14*(1), 52-58.

Hertel, T. W., Lee, H.-L., Rose, S., & Sohngen, B. (2009). Modelling Land-use Related Greenhouse Gas Sources and Sinks and their Mitigation Potential. In T. W. Hertel, S. K. Rose, & R. S. J. Tol (Eds.), *Economic Analysis of Land Use in Global Climate Change Policy* (pp. 123-154). New York, USA: Routledge.

Informetrics. (2007). *General Equilibrium Analysis of Options for Meeting New Zealand's International Emissions Obligations*.

Kooten, G. C. v., Binkley, C. S., & Delcourt, G. (1995). Effect of Carbon Taxes and Subsidies on Optimal Forest Rotation Age and Supply of Carbon Services. *American Journal of agricultural economics, 77*(2), 365-374.

Kooten, G. C. v. (2009). Biological Carbon Sequestration and Carbon Trading Re-visited. *Climatic Change, 95*(2009), 449-463.

Leining, C., & Kerr, S. (2016) Lessons Learned from the New Zealand Emissions Trading Scheme. In*. Motu working paper 16-06*. Wellington, New Zealand: Motu Economic and Public Policy Research.

Lubowski, R. N., Plantinga, A. J., & Stavins, R. N. (2006). Land-use Change and Carbon Sinks: Econometric Estimation of the Carbon Sequestration Supply Function. *Journal of Environmental Economics and Management, 51*(2), 135-152.

Ministry for the environment. (2009). *New Zealand's greenhouse gas inventory 1990-2007*. Wellington, New Zealand.

Ministry for the Environment. (2010). *Land: Land Use*.

Ministry for Primary Industries. (2011). National Exotic Forest Regional Yield Tables.

Ministry for the Environment. (2018). New Zealand's Greenhouse Gas Inventory.

NZIER. (2008). *The Impact of the Proposed Emissions Trading Scheme on New Zealand's Economy*. Retrieved from Wellington, New Zealand.

Rae, A. N., & Strutt, A. (2011) Modelling the Impact of Policies to Reduce Environmental Impacts in the New Zealand Dairy Sector. In*. Department of Economics Working Paper Series, Number 04/11*. Hamilton, New Zealand: University of Waikato.

Rutherford, T. F. (2003). A GAMS/MPSGE Model Based on Social Accounting Data for Tanzania.

Sands, R. D., & Kim, M.-K. (2008). Modelling the Competition for Land: Methods and Application to Climate Policy. In T. W. Hertel, S. Rose, & R. S. J. Tol (Eds.), *Economic Analysis of Land Use in Global Climate Change Policy* (pp. 154-181). New York, USA: Routledge.

Sohngen, B., Tennity, C., Hnytka, M., & Meeusen, K. (2008). Global Forestry Data for the Economic Modeling of Land Use. In T. W. Hertel, S. Rose, & R. S. J. Tol (Eds.), *Economic Analysis of Land Use in Global Climate Change Policy* (pp. 49-71). New York, USA: Routledge.

Stats NZ. (2006). ANZSIC 2006 - Industry Classification.

Tietenberg, T., & Lewis, L. (2016). *Environmental and Natural Resource Economics* (10 ed.). Cambridge, England: Pearson.

Weitzman, M. L. (1974). Prices vs quantities. *The review of economic studies, 41*(4), 477-491.