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Long Term Investment under Uncertain Carbon Prices

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CONTENTS

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ABSTRACT

We use a multi-industry general equilibrium model of the New Zealand economy to analyse the macroeconomic implications of an unexpected fall in the carbon price. Previous research has shown that a lower carbon price produces an unambiguous welfare gain over a higher carbon price; there is less deadweight loss from what is effectively a tax, and less of the country's national income is needed to purchase emission units from other countries.

We are interested in seeing how robust this result is when the reduction in the carbon price is unexpected. Our focus is on events in the electricity generation industry, where strong investment in renewable-based generation under a high carbon price could prove to be inefficient if the carbon price falls.

The results indicate that even at the unexpectedly lower carbon price, using more thermal generation does not raise national economic welfare. This finding is robust to the inefficiency of some capital being stranded in industries that are exposed to a change in the carbon price. There is also a small macroeconomic cost associated with investing in surplus thermal capacity as insurance against lower carbon prices.

1. INTRODUCTION

In NZIER and Infometrics (2009a, 2009b) a number of scenarios are presented which show that, given an international emissions obligation (whereby New Zealand either reduces its emissions or covers any excess by purchasing emission permits from offshore), a lower carbon price is less damaging to national welfare than a higher carbon price – an unsurprising finding.

Most of the reduction in emissions under a carbon charge comes from less thermal electricity generation, especially coal-fired generation – again an unsurprising result.

However, the unsurprising nature of these results is driven largely by two implicit assumptions:

1. That whatever the carbon price, it is the optimal price in the sense of equating the cost of abatement with the value of damage avoided. The model does not know that a lower carbon price could mean incurring more damage from climate change.

2. There is policy certainty. In the modelling investment responds to relative price shifts – notably those caused by the introduction of a carbon price – that do not change over the modelling horizon of 10-20 years or more. Thus investments do not turn out to be inefficient.

In this paper we explore the effects of the second point. That is, if investment occurs under the assumption of a high future carbon price, but the price turns out to be much lower when the investment is in place, do the above (unsurprising) findings still hold?

We use a general equilibrium model of the New Zealand economy to analyse this question.

2. UNCERTAINTY

Most of the existing literature on investment uncertainty looks at optimal investment in the context of uncertainty about climate change, as distinct from uncertainty about climate policy. The perspective is typically that of the firm or industry, so the analytical technique of choice is real options theory. See for example Tuthill (2008). The general conclusion of such research is that uncertainty leads to delays in investment in cleaner (less GHG intensive) technologies. A survey of New Zealand businesses produced the same result.[1] Whether such delays have a negative effect on broader economic welfare is unknown, but is likely to depend on ultimate climate outcomes.

Climate change uncertainty and climate change policy uncertainty are not unrelated. If climate change is uncertain it is more likely that mitigation policy will be vague, with weaker commitments to an emissions target and rent seeking by firms pursuing free emissions permits. These factors make the future path of carbon prices highly uncertain. Even if these factors were minor, uncertainty about abatement technology would continue to cause carbon price volatility.

Addressing policy uncertainty, Schenker (2011) uses a real options approach within a stochastic dynamic general equilibrium model of China. His results show that uncertainty about future carbon prices and when they will be introduced leads to less of a rush to use fossil fuels while they are still competitively priced – that is before the carbon price bites. Thus the effect of policy uncertainty on the environment in the short term is positive.

Nordhaus (2007), extending and revising earlier work with the integrated climate-economy DICE model, demonstrates that setting too high a price on carbon would have large negative welfare effects. This come about because too high a carbon price leads to investment in abatement strategies and technologies that are not efficient when evaluated at the correct carbon price. This also reduces investment in 'conventional' capital which depletes the ability of the economy to respond to higher carbon prices at a later date – should such a scenario occur.

Nordhaus's analysis is global. Ours relates only to New Zealand, uses a less sophisticated model, and does not cover the wide range of issues around climate change policy that are addressed by Nordhaus. Nonetheless the core question is the same: what is the loss associated with basing investment decisions on a carbon price that turns out to be too high?

To keep the analysis manageable we look only at the electricity generation industry as it is most exposed to carbon prices by virtue of its use of fossil fuels and the long-lived nature of its capital stock. There are of course other industries such as metal smelters and cement plants that are exposed to carbon prices, and the vehicle fleet if seen as a collective capital stock would take some time to respond to significant changes in relative fuel costs.

[1] See Numan Parsons et al (2011).

3. Model Scenarios

The model scenarios are designed to answer the following question:

> Does an unexpectedly lower carbon price coupled with investment in electricity generation that is structured on the assumption of a high carbon price, still lead to a better macroeconomic outcome (that a low carbon price has previously shown to be the case) than if the carbon price turns out as expected?[2]

Four scenarios are examined:

- **Scenario 1**: Halved carbon price with surplus thermal generation capacity.
- **Scenario 2**: Surplus thermal capacity without a lower carbon price.
- **Scenario 3**: Halved carbon price without surplus thermal generation capacity.
- **Scenario 4**: Sensitivity test on Scenario 4 with less capital mobility.

Approach

The modelling results are expressed relative to a Business as Usual (BAU) scenario which by 2030 has renewables generation of about 154 PJ, accounting for 84% of generation. This is comparable with MED's (2011) projection of 85%, although the MED has somewhat higher total demand.

The BAU also contains a post-Kyoto international emissions responsibility obligation of 15% below 1990 emissions. That is, if New Zealand does not reduce GHG emissions to 15% below 1990 levels by 2030, it must cover the excess by purchasing emission units from offshore. The world price of carbon is assumed to be $100/tonne of CO_2e and the New Zealand's Emissions Trading Scheme is assumed to be fully integrated into the world price.

The BAU is certainly not a forecast of the economy to 2030. It is simply intended to be a useful if artificial 'baseline' projection of the economy, against which various carbon price and investment scenarios may be compared. Further detail on the BAU is given in Stroombergen (2010). The model is outlined in Appendix A.

In all scenarios 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.
2. Capital market closure: For these scenarios we adopt the short term closure rule whereby the total capital stock is fixed at the BAU level, with endogenous post-tax rates of return on capital. In most modelling the

[2] Clearly the reverse situation could also be analysed – a possibility for follow-up research.

opposite rule is adopted, with fixed rates of return and endogenous total capital formation.

3. External closure: The balance of payments is a fixed proportion of nominal GDP, with the real exchange rate being endogenous. This means that any adverse shocks are 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 unless otherwise noted.

Caveat: There is no endogenous technological change. For example we do not consider endogenous improvements to CCS technology or increases in the efficiency of CCGT power stations in response to different carbon prices.

Modelling Results

Table 1 summarises the results.

Table 1: Summary of Results[3]

	Base #3122	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Private Consumption		0.40	-0.04	0.59	0.58
Exports		-0.06	-0.05	-0.13	-0.72
Imports		0.85	-0.02	1.00	0.96
GDP		0.02	-0.04	0.10	-0.08
RGNDI		0.31	-0.03	0.45	0.45
Real exchange rate		0.19	0.04	0.25	0.47
Real wage rate		0.46	-0.09	0.69	0.31
CO_2e emissions		5.2	-0.1	4.2	2.8
Methane emissions		2.3	0.0	2.3	1.0
Electricity generation	**PJ**	**PJ**	**PJ**	**PJ**	**PJ**
Coal	0.6	0.6	0.6	0.7	0.7
Gas	27.7	40.6	27.5	30.8	28.2
Renewables	153.7	138.6	152.5	153.2	153.8
Total	182.0	179.8	180.6	184.7	182.8

Scenario 1 (halved CO_2 price + reserve thermal capacity)

Halving the carbon price from $100 to $50/tonne makes some renewables generation uneconomic and restores gas generation competitiveness. As a result there is a switch in the generation mix of about 13 PJ. [4]

[3] Some results are shown to two decimal places in order to illustrate differences in effects between macroeconomic variables within scenarios, but may not be accurate to that degree.

[4] The results for Coal are within model error margins.

Economic welfare as measured by RGNDI rises by 0.3%, so the negative effects of having to run more thermal power plant and purchase more emission permits from offshore (due to the 5.2% rise in emissions) are more than offset by the lower emissions price.

However, there is possibly a hidden cost here. If the carbon price does not fall (unexpectedly), there is a considerable amount of unused thermal capacity. We look at this in Scenario 2.

Also, if the carbon price falls unexpectedly and there is no cheaper thermal generation capacity available, would there still be a macroeconomic gain from the reduction in the cost of emission permits? How large is it? We look at this in Scenario 3.

Scenario 2 (surplus thermal capacity)

In Scenario 2 the carbon price is as expected ($100/tonne) but additional thermal reserve capacity is installed which would only become economic at a much lower carbon price. We model this as underutilised capacity.

The extra thermal generation required to meet the renewables deficit in Scenario 1 is 13 PJ or 3600 GWh. Assuming average capacity utilisation implies that about 700 MW of additional generation capacity is required. If it all comes from CCGT at say $1.5m/MW, the cost would be about $1050m, which is the amount put into the model.

The decline in RGNDI is only 0.03% and 0.04% in private consumption. Both changes are within the model error margin, implying no significant macroeconomic cost by 2030 from installing surplus thermal generating capacity. Of course another advantage of this would be as backup in dry years or years of little wind.

Scenario 3 (halved carbon price + no reserve thermal capacity)

Without the ability to switch to the now more competitive thermal generation, the gain in RGNDI is actually slightly more than in Scenario 1. With regard to private consumption the lift is 0.59% compared to 0.40% in Scenario 1.

In other words, while having some reserve thermal capacity and using it when the carbon price encourages it does not cause a macroeconomic loss when there is an unexpected fall in the carbon price, it is actually better not to have capital tied up in such capacity, and not to incur the cost of gas production. Switching to gas fired generation when the carbon price falls from $100 to $50 does not harm economic welfare, but at it is better not to switch at all.

Note that there is a small relative shift to gas in Scenario 3 – about 3 PJ, which is caused by the need to increase generation to meet the higher demand that stems from the lower carbon price.

One result that might look puzzling is the increase in emissions in Scenario 3 at 4.2%, compared to an only slightly higher figure of 5.2% in Scenario 1 where there is much more thermal generation. This is simply because the rise in actual CO_2 emissions (ie not CO_2e emissions) is being camouflaged by the significant increase in methane emissions in both scenarios – about 30% relative to BAU.

Scenario 4: (sensitivity test on Scenario 1)

In Scenario 3 the total capital stock of the economy is fixed at the BAU level, but it is still free to move between industries over the period to 2030 in accordance with the standard putty-clay model of investment. Conceivably though, there could nonetheless be unrealistic movements of capital between industries.

In fact only 0.15% of the total capital stock in the economy moves out of industries that see a fall in output and/or a decline in capital intensity. The largest absolute reductions in capital stock are in Pulp & Paper Production, Machinery & Equipment, Air Transport & Transport Services, Real Estate, and Equipment Hire & Investors in Other Property. However, in all cases the amounts of disinvestment are only 1-2% of capital stocks and so are well below the annual rates of depreciation in those industries. That is, a 12 month period after the realisation that the carbon price is much less than expected, is long enough for new investment capital that was originally destined for say rental housing or industrial premises/plant, to be redirected into other types of investment.

Some of the above industries are not those that would immediately come to mind as losing competitiveness when the carbon price declines; Pulp and Paper for example, or Machinery and Equipment. These industries are mildly carbon intensive compared to the likes of oil refining and cement production, for which a carbon price is unambiguously deleterious. Industries such as Machinery and Equipment lose more from the appreciation of the exchange rate in Scenario 3 than they gain from the lower carbon price – illustrating how consideration of general equilibrium effects can overturn the results of partial equilibrium analysis.

The capital recipient industries and their percentage increases in capital stock are primarily Sheep & Beef Farming (1.4%), Dairy Farming (1.5%), Oil & Gas production (4.4%), Electricity Generation (1.2%), and Ownership of Dwellings (0.1%, but this industry has the largest absolute increase after Oil & Gas). Most of these changes are of no concern. In the space of 12 months not only is potential investment (putty) easily redirected at the margin from rental housing to owner-occupied housing, but existing assets (clay) can in some cases change use, such as between warehouses and residential premises.

Where some concern does arise is with regard to the energy industries, and to a lesser extent farming, where the increase could be rather ambitious. Thus in Scenario 4 we constrain the capital stock in these industries to be no more than in the BAU scenario, with commensurate increases in rates of return.

The results present an interesting picture. As expected the increase in GDP is smaller than in Scenario 3 (indeed it is slightly negative) in accordance with the tighter conditions imposed on capital mobility, effectively making some of it redundant.

Once again though the negative impact on GDP is offset by the reduction in the amount of national income that is needed to purchase emission permits from offshore, a consequence of the severely limited (albeit exogenously imposed) ability of thermal electricity generation to expand.

Conclusion

As discussed in the Introduction previous research demonstrated the unsurprising result that a lower cost of carbon is better for national economic welfare than a higher cost of carbon.

The new research above shows that a lower carbon price is still net beneficial (in terms of RGNDI, but not always GDP) even if it is unexpectedly lower and the capital stock has been configured in the expectation of a higher carbon price. In addition:

- Hedging against a fall in the carbon price by investing in surplus thermal generation capacity (so that the industry can respond quickly to a lower carbon price) has a negligible direct welfare cost, but;
- Actually using that capacity when the carbon price falls reduces the benefit of the lower carbon price. A lower carbon price means that less national income is required to purchase emission permits from offshore. Running thermal power stations partially erodes that benefit.
- The gain to national welfare remains even if the unexpectedly lower carbon price leads to some redundancy of capital stock in industries that lose competitiveness. Although the resulting inefficiency in capital allocation lowers GDP, the effect of this on RGNDI is offset by the value of the reduction in emissions.

How do the results compare with the findings in Nordhaus (2007) mentioned earlier? In Nordhaus's modelling the economic welfare loss from too high a carbon price comes from allocatively inefficient investment – investment aimed at reducing climate change damage when in fact the cost of the damage is over-estimated.

For New Zealand our results show that allocative efficiency is not improved if investment in electricity generation reverts to more thermal generation if the carbon price falls from $100/tonne to $50/tonne. Even at the lower price it is allocatively more efficient (as measured by RGNDI) to maintain a high proportion of renewables-based electricity generation. The reason though is not because of lower damage from climate change. Given its participation in a Kyoto type international agreement the cost to New Zealand from emitting one more tonne of CO_2 is not the damage generated, but rather the cost of purchasing (or not selling) one more emissions unit from other countries.

Clearly it is not in the national interest for about 13 PJ of electricity production to switch out of renewables (mostly wind and geo-thermal) generation and into gas-fired generation when the carbon price falls from $100/tonne to $50/tonne. The switch is driven by changes in Long Run Marginal Cost (LRMC) and substitution elasticities, so perhaps the model's production function in the electricity industry is awry.

Lanz and Rausch (2011) point out that representations of substitution technologies in electricity generation in top-down general equilibrium models are not always consistent with bottom-up data. Further, in reviewing the energy modelling of the Ministry of Economic Development, Energy Link (2010) note that LRMC is not always the best guide to what will happen in any particular market.

Complications include grid constraints, generator offering strategies and uncertain precipitation in hydro lake catchment areas, although Energy Link support the LRMC approach for longer term modelling.

The generation substitution elasticities in the ESSAM model have recently been modified on the basis of research by Evans et al (2011) using a partial equilibrium model of the New Zealand electricity generation system, including allowing for shadow prices on hydro storage. Thus it is unlikely that the model's generation substitution is leading to completely unreliable results.

In the interests of robustness it would of course be prudent to test the above scenarios with a more detailed model of the electricity industry. Of course some differences could be expected as (again to referring to Lanz and Rausch) partial equilibrium models of the electricity industry are insufficient to capture the large inter-industry effects of a carbon price.

Other factors that could lead to different results include:

- Access to lower cost gas, which would alter the opportunity cost of using gas generation plant.
- Faster technological change that reduces the cost of CCS for either gas or coal fired plant, which would reduce the carbon cost of thermal generation.
- A change in carbon prices other than from $100 and $50.

All of these ideas present opportunities for further research on the effects of uncertainty about mitigation policy. It would also be interesting to expand the focus beyond the electricity generation industry. For example what effect would an unexpected change in the carbon price have on the economics of electric vehicles and thereby on economic welfare generally? Similarly with regard to home insulation.

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APPENDIX A: THE ESSAM GENERAL EQUILIBRIUM MODEL

The ESSAM (Energy Substitution, Social Accounting Matrix) model is a general equilibrium model of the New Zealand economy. It takes into account the main inter-dependencies in the economy, such as flows of goods from one industry to another, plus the passing on of higher costs in one industry into prices and thence the costs of other industries.

The ESSAM model has previously been used to analyse the economy-wide and industry specific effects of a wide range of issues. For example:

- Energy pricing scenarios
- Changes in import tariffs
- Faster technological progress
- Policies to reduce carbon dioxide emissions
- Funding regimes for roading
- Release of genetically modified organisms

Some of the model's features are:

- 53 industry groups, as detailed in the table below.
- Substitution between inputs into production - labour, capital, materials, energy.
- Four energy types: coal, oil, gas and electricity, between which substitution is also allowed.
- Substitution between goods and services used by households.
- Social accounting matrix (SAM) for tracking financial flows between households, government, business and the rest of the world.

The model's output is extremely comprehensive, covering the standard collection of macroeconomic and industry variables:

- GDP, private consumption, exports and imports, employment, etc.
- Demand for goods and services by industry, government, households and the rest of the world.
- Industry data on output, employment, exports etc.
- Import-domestic shares.
- Fiscal effects.

Model Structure

Production Functions

These equations determine how much output can be produced with given amounts of inputs. For most industries a two-level standard translog specification is used which distinguishes four factors of production – capital, labour, and materials and energy, with energy split into coal, oil, natural gas and electricity.

Intermediate Demand

A composite commodity is defined which is made up of imperfectly substitutable domestic and imported components - where relevant. The share of each of these components is determined by the elasticity of substitution between them and by relative prices.

Price Determination

The price of industry output is determined by the cost of factor inputs (labour and capital), domestic and imported intermediate inputs, and tax payments (including tariffs). World prices are not affected by New Zealand purchases or sales abroad.

Consumption Expenditure

This is divided into Government Consumption and Private Consumption. For the latter eight household commodity categories are identified, and spending on these is modelled using price and income elasticities in an AIDS framework. An industry by commodity conversion matrix translates the demand for commodities into industry output requirements and also allows import-domestic substitution.

Government Consumption is usually either a fixed proportion of GDP or is set exogenously. Where the budget balance is exogenous, either tax rates or transfer payments are assumed to be endogenous.

Stocks

The industry composition of stock change is set at the base year mix, although variation is permitted in the import-domestic composition. Total stock change is exogenously set as a proportion of GDP, domestic absorption or some similar macroeconomic aggregate.

Investment

Industry investment is related to the rate of capital accumulation over the model's projection period as revealed by demand for capital in the horizon year. Allowance is made for depreciation in a putty-clay model so that capital cannot be reallocated from one industry to another faster than the rate of depreciation in the source industry. Rental rates or the service price of capital (analogous to wage rates for labour) also affect capital formation. Investment by industry of demand is converted into investment by industry of supply using a capital input- output table. Again, import-domestic substitution is possible between sources of supply.

Exports

These are determined from overseas export demand functions in relation to world prices and domestic prices inclusive of possible export subsidies, adjusted by the exchange rate. It is also possible to set export quantities exogenously.

Supply-Demand Identities

Supply-demand balances are required to clear all product markets. Domestic output must equate to the demand stemming from consumption, investment, stocks, exports and intermediate requirements.

Balance of Payments

Receipts from exports plus net capital inflows (or borrowing) must be equal to payments for imports; each item being measured in domestic currency net of subsidies or tariffs.

Factor Market Balance

In cases where total employment of a factor is exogenous, factor price relativities (for wages and rental rates) are usually fixed so that all factor prices adjust equi-proportionally to achieve the set target.

Income-Expenditure Identity

Total expenditure on domestically consumed final demand must be equal to the income generated by labour, capital, taxation, tariffs, and net capital inflows. Similarly, income and expenditure flows must balance between the five sectors identified in the model – business, household, government, foreign and capital.

Industry Classification

The 53 industries identified in the ESSAM model are defined on the following page. Industries definitions are according to Australian and New Zealand Standard Industrial Classification (ANZSIC).

Input-Output Table

The derivation of the underlying input-output table is given in Stroombergen (2008).

1	HFRG	Horticulture and fruit growing
2	SBLC	Livestock and cropping farming
3	DAIF	Dairy and cattle farming
4	OTHF	Other farming
5	SAHF	Services to agriculture, hunting and trapping
6	FOLO	Forestry and logging
7	FISH	Fishing
8	COAL	Coal mining
9	OIGA	Oil and gas extraction, production & distribution
10	OMIN	Other Mining and quarrying
11	MEAT	Meat manufacturing
12	DAIR	Dairy manufacturing
13	OFOD	Other food manufacturing
14	BEVT	Beverage, malt and tobacco manufacturing
15	TCFL	Textiles and apparel manufacturing
16	WOOD	Wood product manufacturing
17	PAPR	Paper and paper product manufacturing
18	PPRM	Printing, publishing and recorded media
19	PETR	Petroleum refining, product manufacturing
20	CHEM	Fertiliser and other industrial chemical manufacturing
21	RBPL	Rubber, plastic and other chemical product manufacturing
22	NMMP	Non-metallic mineral product manufacturing
23	BASM	Basic metal manufacturing
24	FABM	Structural, sheet and fabricated metal product manufacturing
25	MAEQ	Machinery and other equipment manufacturing
26	OMFG	Furniture and other manufacturing
27	EGEN	Electricity generation
28	EDIS	Electricity transmission and distribution
29	WATS	Water supply
30	WAST	Sewerage, drainage and waste disposal services
31	CONS	Construction
32	TRDE	Wholesale and retail trade
33	ACCR	Accommodation, restaurants and bars
34	RDFR	Road freight transport
35	RDPS	Road passenger transport
36	RAIL	Rail transport
37	WATR	Water transport
38	AIRS	Air transport and transport services
39	COMM	Communication services
40	FIIN	Finance and insurance
41	REES	Real estate
42	EHOP	Equipment hire and investors in other property
43	OWND	Ownership of owner-occupied dwellings
44	SRCS	Scientific research and computer services
45	OBUS	Other business services
46	GOVC	Central government administration and defence
47	GOVL	Local government administration
48	SCHL	Pre-school, primary and secondary education
49	OEDU	Other education
50	HOSP	Hospitals and nursing homes
51	OHCS	Other health and community services
52	CULT	Cultural and recreational services
53	PERS	Personal and other community services