Reducing Carbon Emissions? The Relative Effectiveness of Different Types of Environmental Tax: The Case of New Zealand

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Abstract: Although countries experiences on environmental taxation differ, discussions in New Zealand coincide with the recent announcement by the government of a new carbon tax and a new energy tax to be introduced before the first phase of the Kyoto protocol. This paper provides preliminary simulation results that may help answer some policy-related questions including the relative micro- and macro-level impacts of energy taxes or carbon taxes and the likely impacts of the carbon taxes on the competitiveness of energy intensive industries.

Keywords: Carbon tax, greenhouse gas emissions, CGE model

1. Introduction

Recent debates in the literature (Parry, 1995, Parry *et.al.*, 1999; Bovenberg and Goulder, 1996) on the likely economic and social impacts of alternative types of environmental taxation have highlighted the importance of issues including externalities, environmental concerns, double dividend, revenue neutrality and equity. The recent Kyoto Protocol (henceforth, KP), has further reinforced the importance of these issues. The issues also raise the need for empirical-based analysis to guide policy makers. Indeed, it is partly this need that has generated a vast amount of literature studying some of the environmental and economic issues relating to international agreements such as the Kyoto Protocol. A challenge for many of the studies is to find options that 'maximize society welfare' and at the same time reduce greenhouse gas emissions (henceforth, GHG) and its likely costs.

In the New Zealand context, some of the recent discussion has focused on conceptual issues relating to for example, revenue recycling, double dividends. Furthermore, there has been discussion of the likely impact of the KP on the environment, economic performance (eg. economic growth, competitiveness, employment, investment etc.) and income distribution. To date the New Zealand government seems to favour a combination of energy taxes, fuel taxes and carbon taxes. Additionally, there is on-going discussion related to the alignment of the government's favoured policies with their implementation and governance, and the economic and social instruments that may be used to pursue those policies. Introducing a carbon tax may result in welfare losses. Does this imply that a policy committed to their introduction means that the macro and micro-economic impacts of an energy tax or fuel tax are more acceptable to New Zealanders? Are all sectors in the New Zealand economy likely to bear, equally, the adjustment costs as New Zealand ratifies the KP? What is the likely impact on economic growth, employment, investment and other macro-economic variables? What are the likely impacts on firms? This paper attempts to answer some of these questions using a CGE model of the New Zealand economy. The model is specifically designed to focus on the energy sector and can simulate the effects of, in particular, three types of GHG taxes: an energy tax on all fossil fuels, a carbon tax and finally a fuel tax on petroleum products.

The paper is constructed as follows. Section 2 discusses the economics of carbon taxes and some international experiences. Section 3 briefly outlines the structure of the CGE model used and Section 4 discusses the simulation results. The final section concludes and summarizes the findings.

2. The economics of carbon taxes and related issues

The fundamental theoretical basis of environmental taxes have been well documented (early discussions include Baumol, 1972; Baumol and Oates, 1971, 1988) and will only be briefly discussed in this section. TheThTT This early literature showed that society's welfare would be improved if there were a tax on a good whose consumption or production resulted in a negative externality. Baumol and Oates (1971) further argue that an environmental tax would minimize the costs to society and at the same time achieve an 'environmental greening' objective when a negative externality to society existed. However, there is still no general consensus on the effectiveness of alternative instruments available to policy makers where they include, energy taxes, carbon taxes, subsidies and transfers. The main issue here is 'which instrument or combination of instruments would be optimal?' A carbon tax may be regressive as it may affect poorer households disproportionaly (Ekins and Parker, 2001). With any regressive tax, however, this may be resolved by reducing other taxes or the introduction of transfers, which may offset the negative impact of carbon taxes on poor households. Poor households may have the tendency to buy cheaper and perhaps less energy-efficient appliances than richer households. A carbon tax may also be advantageous to the economy if it lowered other taxes that are perceived to be more distortionary. This may include labour income taxes see for example, (Barker, 1995). On the other hand, Goulder (1995) argues that a carbon tax is more distortionary than labour tax because of too narrow tax base, the possibility of double taxation (i.e. on both intermediate input and final output) and its non-uniform content in energy products. Furthermore, Gaskins and Weyant (1993) have argued that the introduction of a carbon tax may create more distortions because of the extent to which a carbon tax or environmental change affects the prices faced by both consumers and producers. Thus, the debate on the effectiveness of a carbon tax remains active and ongoing.

A recent survey by Ekins and Barker (2001) on carbon tax and carbon emission trading concluded that "market based instruments of carbon control will achieve a given level of emissions reduction at lower cost than regulations." (p.368). Studies on the effectiveness of a carbon tax have generally concluded, however, that it generally achieves its objective of reducing GHG emissions.

2.1. *Carbon Taxes and International Experience*

Although a carbon tax is a relatively new option for to New Zealand, many other countries for example, The Netherlands, Norway, Sweden, Denmark, Finland and Switzerland introduced such taxes in the early 1990s. In fact, the majority of EU member states have used carbon taxes at some stage to reduce GHG emissions. The literature on this is extensive see Ekins and Barker (2001) for a review and will not be discussed in detail here.

The experiences of European countries, however, may have important lessons for New Zealand where special importance may be attached to the so called "eco-leaders," Denmark, Netherlands, Norway and Sweden. Other countries for example, Austria, Belgium, Finland, Germany and Switzerland have made small, but continuing steps towards a greater role to be played by CO_2 taxes in their economy. These countries may also offer important lessons, but currently they are typically less important than those from the "eco-leaders" on which we will now concentrate.

The introduction of the carbon taxes by the "eco-leaders" generally involves three components. First, subsidies and taxes that may be distortionary are either modified or removed. Secondly, taxes are restructured including legislation to align them with environmental objectives. Thirdly, the new green taxes are introduced (Ekins and Barker, 2001). With these three main aspects identifies, a few observations and lessons may bee drawn from the literature.

Bruce *et. al.* (1996) and Barker and Kohler (1998) have shown that eco-taxes can be regressive using data for OECD countries. Especially vulnerable are poorer households who may be hard hit by eco-taxes. However, the experience of the eco-leaders is that it is possible for the regressive tendency of eco-taxes to be moderated. In addition, eco-taxes may have trade-offs that are absent in other forms of taxation. In some European countries (eg. Norway, Finland, Austria and Denmark) for example, there is no leaded gasoline as high taxes have eliminated it from their respective markets (Ekins and Parker, 2001). This results in a change in consumption patterns where consumers substitute leaded gasoline for high GHG products, but at the same time keeping a large tax base (i.e. unleaded gasoline).

From the literature discussed above, one can perhaps conclude that the experiences of the European eco-leaders seem to show that countries like New Zealand should not expect the eco-taxes to yield significant revenues, but should be encouraged by the fact that eco-taxes are likely to achieve environmental goals rather than fiscal objectives. However, one can argue that environmental taxes to reduce GHG can be used to reduce labour costs and, with revenues recycled back to industries and households, this is possible to cut energy consumption, create jobs and at the same time remain competitive.

2.2 *New Zealand Government's Preferred Policy*

The New Zealand government seems to prefer a combination of energy taxes, fuel taxes, carbon taxes and other measures. Other measures may include the new waste strategy announced in March 2002 introduced specifically to reduce the GHG emissions from the waste sector. In addition, other measures may also include an announcement that the government intends to fund measures to save electricity in the public sector by about 15%. Current policies as outlined in the government's Energy Efficiency and Conservation Strategy, are estimated to cut GHG emissions by 25 million tonnes.

The target for New Zealand, however, is to reduce emissions by about 365 million tonnes of CO2 equivalent in the first phase. This may be achieved by a range of measures including sink credits and environmental taxation. The government seems to support carbon taxes as in May 2002 they announced a new carbon tax to be introduced by 2007. The revenue from the carbon tax is expected to be recycled back through the tax system. The government does not plan to use the revenue to improve its own fiscal position. The introduction of the new carbon tax may result in an increase in the price for fuels. For example, if the price of carbon dioxide is NZ$25 a tonne tax, then this would raise retail petrol prices by around six percent, diesel by around 12 percent, electricity by around nine percent, gas by around eight percent and coal by around 19 percent.In addition to the new carbon tax, the government is also planning to introduce a new energy tax, which might be introduced by 2007.

3 The Model

The model used here follows Dixon *et.al*. (1982) with the extensions by McDougall (1999), Truong (1999) and Hamasaki and Truong (1999) where there is an emphasis on modelling an energy sector which allows inter-fuel and capital-energy substitution possibilities. Furthermore, the model has structures that support both long-run and short-run analysis following McDougall (1999). The model also has various enhancements that enable it to be more detailed than the standard CGE model. We will concentrate on the comparative static side of the model to shed light on some of the issues raised above. The model represents an energy version of ORANI (Dixon *et.al.* 1982; McDougall, 1999), where investment is modelled in a way such that its initial value is proportional to the size of investments at the end of the simulation period. In turn, the size of the capital stock at the end of the period may be affected by exogenous shocks. The change in the size of the capital stock at the end of a simulated period causes changes in the growth rate of the capital stock. This treatment of investment follows closely with the suggestions by Horridge (1985).

The main sectors in the model are the government, households and industries. The government sector is modelled as a collector of taxes, which are partially transferred to households. There is a constraint in the government such that its expenditure, including transfers, is equated with tax revenue. This is achieved by using two variables to model the government's budget balance following McDougall (1999). The introduction of these two variables constrain the government's expenditure to not only equal tax revenue but also, constrain the choice of tax rate should to achieve a certain tax revenue to balance the government's account.

The household sector is modelled such that it is the sole owner of all the factors including land and capital which means the sector has several sources of income. In addition to the standard household disposable income, households also receive income from other factors and non-labour income. The net wealth of the household is therefore determined by the value of income from labour, land and capital as well as their savings rate at the end of a simulation period. The values of the land and capital are given (exogenous) in the model. The balance between these three items represents the household's net debt. This formulation determines how domestic physical capital is financed where it can either be financed internally by household's net wealth or financed externally. In the second case, household's net debt might increase.

The household sector also has a consumption function, which is simply the value of the product of the household's total labour income and the household's propensity to consume. The household labour income is assumed to be net disposable income where income tax is deducted from the household's gross disposable income. Household's total income, however, is the sum of the income from land, capital and labour and transfers from government.

The other main sector in the model is the industry sector. Here we follow closely the structure of production presented in McDougall (1999) and Abayasirisilva and Horridge (1996). Industries are modelled so that they can use the given factors to produce either a single or multi products. As each industry can either produce multi- or a single product with a number of different inputs, the modelling task is to allow for the separation of these products and inputs (Abayasirisilva and Horridge, 1996). The separability assumption allows flexibility in the production sector and also makes it easier to estimate the parameters as it reduces the number of parameters to be estimated. In this model, the separable function of the output is derived from a constant elasticity of transformation aggregation function. The input separable function is divided into a number of nests. At the top of the nests for the input function, there is a composite commodity, which is a combination of the primary factor and 'other' costs. The composite commodities are combined using a Leontief production function. This implies that all inputs are used in proportion to Y, an index of the activity in that industry. Like many other CGE models, the Armington (1969) assumption is used. This means that the composite commodity produced is a constant elasticity of substitution function of either a domestic good or its imported equivalent.

The composite input of the primary factor is a constant elasticity of substitution combination of land, capital and composite labour. The composite labour is a constant elasticity of substitution of skilled and unskilled labour. This combination of composite primary input is the same across all the industries, (in our case 22). However, this does not imply the same composite input and labour combination for every product produced because the input combination and the behavioural parameters are not the same across the 22 industries.

Production and consumption in the household and industrial sector are affected by 'bad commodities', which are oil, gas, coal and electricity through the environmental taxes imposed on these 'bad commodities.' This is achieved by the introduction of three environmental taxes: carbon taxation, energy taxation and petroleum taxation. These taxes form part of the *ad valorem* commodity tax.

The impact of these 'bad' taxes depends on the value of the intensity coefficients. The intensity coefficients for each of the taxes are the proportion of the 'bad contents' to the market value of the commodities. The 'bad content' is the energy content of the three types of taxes discussed. It is possible that the 'bad content' can be disaggregated into different types of fuels. For example, electricity can be disaggregated into steam turbine, hydroelectricity, gas turbine, coal generators and so forth. Coal, a fossil fuel, can also be disaggregated into lignite (brown coal) and briquettes. In this model, however, disaggregation of fossil fuels is left to a later study and not discussed further here.

4 Simulation and Results

The simulations undertaken included the introduction of an energy tax, a carbon tax and a petroleum tax and measure the impact of each on the economy when the rate of taxation is set so that each type tax collects revenue equivalent to 0.6 percent of GDP in the base-case. Table 1 presents the tax rate set for each of the taxes. As the table shows, the tax rates for both the energy and carbon tax are not very different.

The tax rate is highest for the energy commodity with the high energy intensity as well as high emission coefficients. The highest *ad valorem* tax rates are for coal while the lowest tax rates are for petroleum, oil and gas products. The simulation results were constructed to consider, in particular, the existence of likely significant differences in the micro and macro impacts of an energy tax, a carbon tax and a petroleum tax. The emphasis was particularly on understanding both the greenhouse impact and the non-greenhouse impact of the various environmental taxes.

Table 1: Ad valorem tax rates on fossil fuels (%)

	Energy tax	Carbon tax	Petroleum products tax
Coal	131	123	0
Gas	56	51	0
Oil	14	18	0
Petroleum products	8	9	15

The results of the impact of each of the environmental taxes on the carbon emissions and fossil fuel consumption shows that both the volume of carbon emissions and fossil fuel consumed declined (Table 2). The carbon tax, for example, leads to a reduction in energy consumption and carbon emission of about 14 and 18 percent respectively. The impact of the energy tax and carbon tax in reducing energy consumption and carbon emission are almost the same. An energy tax reduces energy consumption by 13 percent compared to 14 percent for the carbon tax. It also reduces carbon emissions by approximately 16 percent compared with 18 percent for the carbon tax. On the other hand, a petroleum tax is less effective in reducing energy consumption and carbon emissions as it reduces carbon emission and energy consumption by approximately 0.9 and 1.9 percent, respectively.

Table 2: Estimated effects of each of the three taxes on fossil fuel energy consumption and carbon emissions

	Energy tax	Carbon tax	Petroleum products tax
Carbon Dioxide Emissions	-14	-18	-0.9
Fossil fuel energy use	-13	-16	-1.9

Turning to the macro effects of the three types of taxes, the impact of both the carbon and the energy taxes on some macro variables are similar, as shown by Table 4. Real household consumption falls by 0.1 percent for the carbon tax and 0.09 percent of the energy tax. However, for the petroleum tax, consumption falls by 0.2 percent. Additional tax will incur a high penalty for the economy, with little effect on the environment.

Table 3: Estimated effects of energy, carbon and petroleum products taxes on selected macro variables

	Petroleum product tax	Energy tax	Carbon tax
Income tax rate	-0.82	-0.62	-0.68
Household consumption	-0.2	-0.09	-0.1
Capital (working)	-0.82	-1.12	-1.26
Volume of exports	-1.62	-1.54	-1.7
Capital (fixed)	-0.75	-1.58	-1.62
Investment	-0.32	-0.51	-0.54
GDP	-0.29	-0.38	-0.39
Volume of imports	-0.91	-0.78	-0.89

Like many CGE models that model the impact of energy and carbon emission reduction programmes, the impact of both the energy tax and the carbon tax is to reduce GDP by approximately 0.385 percent. The impact of the petroleum tax is slightly less, at 0.29 percent. The fall in GDP is associated with the fall in capital stock. As the capital stock is reduced investment also falls. The impact of the energy tax and the carbon tax on investment is approximately 0.51 and 0.54 respectively with the carbon tax having a slightly higher effect than the carbon tax.

In addition, we can consider the impact in selected sectors, as shown in Table 4. The sectoral effects presented here relate to the energy intensive industries, mining, metal products, electricity and gas sectors. The impact on these energy intensive sectors exceeds, on average, 2 percent.

For example, for mining there is a reduction of 4.1 and 4.5 percent with the energy and carbon tax respectively. The impact of the petroleum tax on mining is slightly less at approximately 2 percent. The impact on the metals' sector and the electricity, gas and water sectors is also a decline of, an average, 3.8 percent for the metal sector and an average reduction of about 2.7 for the electricity, gas and water sector. The slightly less than average impact on the electricity, gas and water sector is due to the 1.2 percent increase in electricity, gas and water sector usage with a corresponding reduction in usage for the energy and carbon taxes. The other sectors are slightly less energy intensive than the previous three sectors discussed so the impacts of the three taxes are less than those of the energy intensive sectors. Generally, the impact of the energy taxes and the carbon taxes are greater than the petroleum taxes.

Table 4: Estimated effects of energy, carbon and petroleum products on activity of selected sectors

	Petroleum product tax	Energy tax	Carbon tax
Services	-0.26	0	0
Petroleum prod.	-1.62	-1.52	-1.34
Construction	-0.62	-0.93	-0.8
Mining	-2	-4.12	-4.51
Transport	-0.71	-0.55	-0.5
Wood products	-0.41	-0.43	-0.52
Transport equip.	-0.64	-0.52	-0.43
Electricity	1.27	-3.21	-3.62
Textiles	0	0	0
Non-metal products	-0.81	-0.72	-0.91
Agriculture	-0.4	-0.31	-0.42
Metal products	-3.12	-3.66	-3.92
Food Products	-0.11	0	0

In addition to the output impacts on the above selected sectors, there are also employment effects. Table 5 shows the impact of the three taxes on employment broadly divided into skilled an unskilled. The impact of the taxes if felt most heavily on the unskilled workers with a reduction of 0.23 percent for the energy tax and 0.28 for carbon tax.

Table 5: Estimated effects of energy, carbon and petroleum products on employment

	Energy tax	Carbon tax	Petroleum product tax

Skilled Workers	0.15	0.16	0.02
Unskilled Workers	-0.23	-0.28	-0.06
Overall Employment	0.00	0.00	0.00

On the other hand, there is an increase in the level of employment of skilled workers. This may signal a change in the structure of the economy where firms prefer to substitute labour for less energy intensive capital.

5 Conclusions

This paper attempts to assess the relative effectiveness of an energy tax, a carbon tax and a petroleum tax on the New Zealand economy. From the European experience we have learned that targeting carbon dioxide can be an efficient way to achieve environmental goals although efforts should be made to reduce the emissions of other harmful GHG such as sulphur dioxide, nitrogen oxide and methane as they are more effective in trapping heat in the earth's atmosphere.

This exercise has demonstrated that an energy tax based on the energy content of fossil fuel might be an effective instrument to reduce carbon emissions although the energy tax is not as effective as a carbon tax. Policy instruments such as a carbon tax might reduce the stock of both fixed and working capital. The reduction in the economy's stock of capital might lead to reductions in GDP, household consumption (an indicator of welfare change) exports and investment. Therefore, some important trade-offs exist and require consideration.

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