# GREENHOUSE

## COPING WITH CLIMATE CHANGE

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# MODELLING THE EFFECTS ON THE NEW ZEALAND ECONOMY OF THE USE OF ECONOMIC INSTRUMENTS TO REDUCE CARBON DIOXIDE EMISSIONS

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## *Abstract*

*The standard framework for analysing the economic impact of carbon emission abatement is the cost–benefit approach, which estimates the cost of abatement and compares it with the benefits (avoided damage) over a range of abatement options. Recognised problems with this methodology include the treatment of uncertainty, the use of a positive discount rate, and the difficulty of evaluating dynamic processes such as technological change. A major advantage of cost–benefit is its ability to utilise the quantitative results from economy-wide computable general equilibrium models.*

*Results from a series of such model experiments simulating the economic effect of carbon taxes in New Zealand are compared, with particular attention paid to modelling work commissioned by the Ministry for the Environment in 1993. The results suggest that New Zealand could impose a unilateral carbon tax without causing any clear-cut damage to either its international competitiveness or the level of GDP, provided that the overall fiscal package is appropriately structured. In contrast to Australian findings, the carbon tax emerges as a more powerful instrument than an energy tax in the New Zealand case. The low, possibly negative, abatement costs estimated for New Zealand overlap with parallel studies in the USA, though most computable general-equilibrium (CGE) abatement cost estimates for the US economy are positive.*





## INTRODUCTION

A near-consensus of scientific opinion has convinced the world's governments of the need to reduce emissions of greenhouse gases. The 1992 Framework Convention on Climate Change was the result. The question of how emissions reduction can be achieved has been passed to two broad groups: the engineers, whose work often suggests that it is technically feasible to switch the world energy system off its present dependence on fossil fuels (Goldemberg *et al.*, 1988; Lovins and Lovins, 1991; Johansson *et al.*, 1992; Johansson and Swisher, 1993); and the economists, whose work has focused on the design of effective policy instruments to steer the economic system in that direction at least cost.

The economic research effort has proceeded on three main fronts. First, there has been a rapid development of thinking on the design of so-called 'economic instruments' to achieve emission abatement. The front runners are a tradeable emission permit scheme and a global carbon tax, the relative merits of which remain finely balanced (OECD, 1993b; UNCTAD, 1992; Dornbusch and Poterba, 1991; Hoel, 1991; see Bertram, 1993 for other references).

Second has been a burst of 'top-down' general-equilibrium economic modelling work.[1] An international modelling exercise coordinated by the OECD has simulated the effects of economic instruments, generally using a global carbon tax as the experimental variable.[2] The results of that research (Dean, 1993) indicate that global abatement is achievable, but imposes significant cost to the world economy in terms of foregone output, even when a century is allowed for adjustment to take place, unless human economic behaviour changes from that observed in the past and/or the entry cost of 'backstop' abatement-promoting technologies falls sharply.

The Framework Convention placed the initial policy focus on action by the governments of individual countries, rather than on collective adoption of a global policy instrument. A large number of economic modelling studies have investigated the effects on single countries, or groupings such as the European Community, of the adoption of national or regional taxation packages designed to reduce emissions from the target economy. The New Zealand study reported later in this paper falls into this body of research. It uses the standard research technique of subjecting a comparative-static, general-equilibrium model of the economy to a 'shock' consisting of a package of tax changes, and then observing the resulting change in the model economy's key variables, including its carbon emissions.

1 The term 'top–down' is used to refer to the general-equilibrium modeller's practice of taking a model of the economy with given behavioural parameters, imposing some particular change or set of changes on the model 'from above', and observing the resulting change in the equilibrium solution. The contrasting approach of the engineers, often called 'bottom–up', involves identifying technical solutions to the emissions problem and estimating the costs and benefits for individual economic agents of adopting the required innovations. Top–down work has tended to be far more pessimistic about the costs of abatement than bottom–up work, highlighting the importance of behavioural change and implementation costs in achieving reduced carbon emissions (see Dean, 1993; Johnstone, 1994).

2 In general-equilibrium models, there is no clear distinction between carbon taxes and tradeable permits since for any given level of achieved abatement, the required carbon tax will be equal to the market price of permits, reflecting the 'shadow price' of marginal abatement.

A third research front has developed recently as dissatisfaction grew with the orthodox cost–benefit approach which has been widely used to interpret the model results obtained to date. Working Group III of the Intergovernmental Panel on Climate Change (IPCC), for example, revised its work program early in 1994 to consider alternatives to the cost–benefit approach. One of these is the 'option' approach to investment decisions in circumstances where the decision-maker is faced with irreversible costs combined with a high degree of uncertainty about the future paths of key variables (Dixit and Pindyck, 1994). The timing of the decision then becomes part of the decision process itself, and economic modelling can address directly the question of whether to act now or to wait for more information (i.e. take an option to act in the future).

An advantage of the options method is its dynamic character which enables explicit account to be taken of the time paths of various parts of the problem, in contrast to the essentially static cost–benefit approach which seeks to 'collapse' the entire future into a single present value, using shadow prices and a single discount rate[3]. At this stage, however, the literature contains only theoretical results from this work as it relates to the greenhouse gas issue. The New Zealand Government's recent deferral until 1997 of its decision on whether to adopt a carbon charge (Upton 1994) could possibly be rationalised in terms of this theoretical approach[4], but the Minister for the Environment's announcement indicates merely that the Government bowed to strong industrial lobbying for voluntary compliance as an alternative to economic instruments.

## General equilibrium modelling of abatement cost in a cost–benefit framework

Figure 1 shows the conceptual framework which motivates most economic modelling work on greenhouse gas abatement, and related attempts to estimate the 'optimal' level of abatement effort (Nordhaus, 1991, 1993a; Cline, 1992; Dean, 1993; Pearce *et al.*, 1994).

At first sight the model is disarmingly simple. Increasing emission-abatement effort is measured from left to right across the diagram, and the assumption is made that there is a negative relation between abatement effort and global warming (i.e. more abatement translates to less warming). Costs and benefits are measured vertically in some unit of account (denoted \$) in which it is assumed to be possible to express all relevant effects. Two curves are then drawn in Figure 1a. One shows the rising total cost of abatement as effort is increased, with the curve convex downward to reflect the usual economists' assumption that firms and households will adopt the lowest-cost abatement options first and then rank the remaining options in merit order, so that higher levels of abatement are

[3] In passing, it may be noted that Dixit and Pindyck's option approach does not resolve the issue of what social discount rate should be used in making decisions. Their model provides an alternative to the common cost–benefit approach of dealing with uncertainty simply by raising the discount rate, but leaves unresolved the debate over whether or not the social rate of time preference should be positive. On the case for a zero discount rate see Cline (1992).

[4] It should however be emphasised that an empirical application of the options model would not necessarily support deferring the decision of whether to take abatement action on greenhouse gases. The model would balance the irreversible 'opportunity costs' represented by premature obsolescence of some installed capital equipment against the 'opportunity benefits' gained by an early start on abatement.





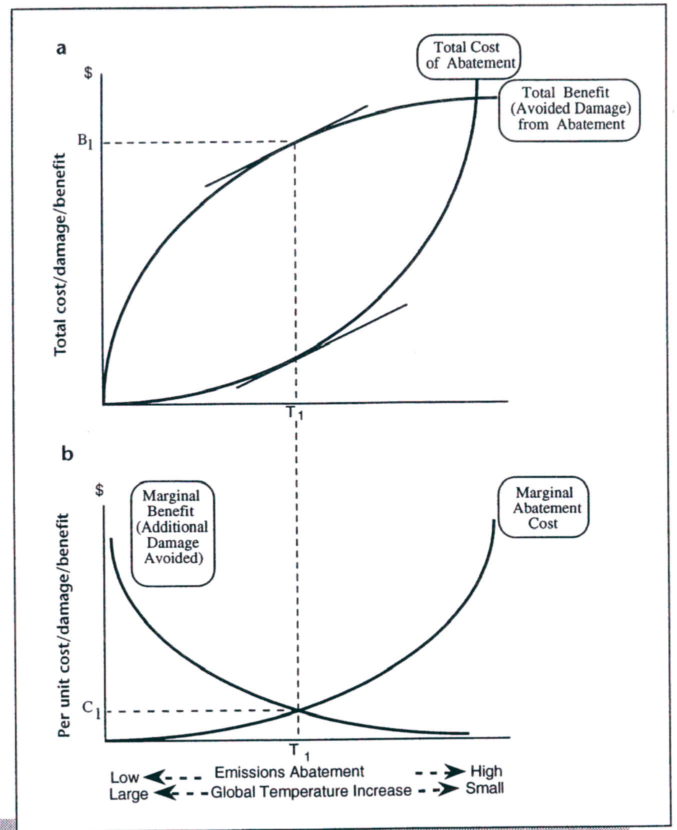


Figure 1. Schematic cost–benefit framework for global warming analysis

achieved at higher cost. It should be noted that this assumes given technology (or in dynamic terms, a rate of technological progress which is exogenously given and so is unrelated to the amount of abatement effort).

The other curve in Figure 1a is the total damage schedule, which shows the benefit gained from abatement in terms of the amount of damage from global warming that is avoided as abatement effort increases. The curve is concave downward, which reflects the assumptions that (i) substantial damage is expected to be associated with no or low abatement effort, (ii) damage declines continuously with increasing abatement, and (iii) as high levels of abatement are achieved, avoidable damage becomes lower and the pay-off to additional abatement effort therefore flattens out.

Figure 1b shows the marginal abatement and marginal damage curves derived from the slopes of the total abatement and total damage schedules in the top panel. The cost–benefit decision rule is to choose the level of abatement effort $T_1$ at which the marginal abatement cost is equal to the marginal benefit (damage avoided), corresponding to the maximum

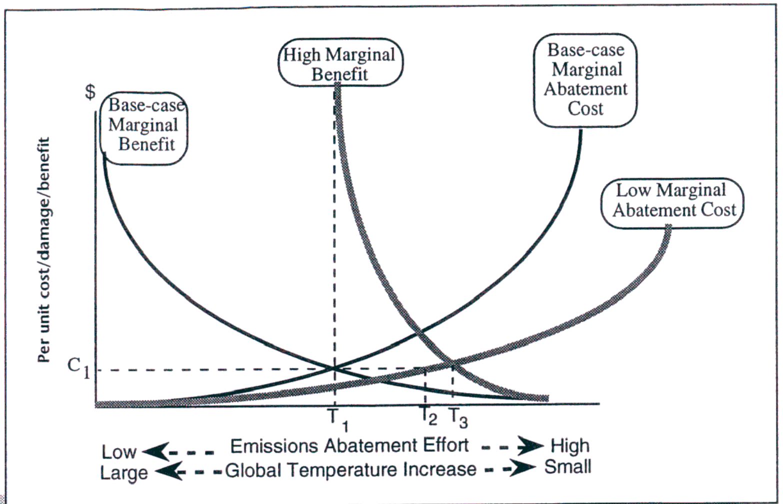


**Figure 2.** Implications of incorrect forecasting of damage and abatement cost

attainable excess of benefit over cost in the top panel. Above this level of abatement, each extra 'dollar' devoted to abatement yields less than a dollar's worth of avoided damage, and hence represents excess abatement relative to the economic optimum.

Nordhaus (1991, 1994) has pioneered the estimation of the marginal abatement cost and marginal benefit schedules. His work produces a low estimate of optimal abatement effort and very cautious recommendations: a carbon tax in the vicinity of US$5 $t^{-1}$ C at the turn of the century, rising to perhaps $20 $t^{-1}$ C by the year 2100. More aggressive abatement efforts, Nordhaus argues, would be irrational because marginal benefits would be outweighed by the higher marginal costs of abatement.

Critics of Nordhaus within the cost–benefit paradigm such as Cline (1993b), Ekins (1994) and Williams (1994) argue that he has overestimated abatement cost, underestimated the damage function, and failed to allow for the uncertainties and long time frame surrounding the whole greenhouse issue. Other estimates of global damage from business-as-usual emissions, assembled for IPCC Working Group III, show Nordhaus' damage estimates to lie at the bottom of the range found by studies to date (Pearce *et al.*, 1994, Table 3.6.1).

The general thrust of these arguments can be captured in the static cross-sectional framework of Figure 1. Consider Figure 2, where the 'expected' marginal schedules from Figure 1 are drawn together with a radically higher marginal damage curve and a radically lower marginal abatement cost curve. In the case where the true benefit and cost schedules turn out to be the High Marginal Benefit and Low Marginal Abatement Cost curves in Figure 2, it can be seen that a decision to abate to the level $T_1$, even if implemented, will result in extreme damage which could have been avoided at far lower cost than was expected when the decision was made. After the event it would then be seen that abatement effort should have been greater: at $T_2$.[5]





**A number of writers, sometimes loosely referred to as the 'sustainability school', argue** that uncertainty about the effects of global warming is such that policy now should be premised on the worst case shown by the High Marginal Benefit curve in Figure 2, in order to minimise possible regret and avoid even a small probability of a catastrophic outcome.[6] From this point of view it may be argued that the cost of early aggressive abatement action should be interpreted as the purchase by the global community of the option to raise its emissions again in future if new information reveals the costs of global warming to be mild. Because of the irreversible nature of greenhouse-related environmental damage (at least over the time frame of a couple of centuries), failure to purchase such an option now (i.e. adoption of a low-abatement strategy) may foreclose the world community's future ability to abate sufficiently to avoid damage, if the scientific worst-case scenario eventuates.[7] The 'Marshallian' equalisation of expected marginal cost and marginal benefit on which orthodox cost–benefit rests then ceases to provide the appropriate guide to action.

In addition to the problems posed by uncertainty, there are serious conceptual difficulties with the treatment of time in the cost–benefit framework. The greenhouse process is a dynamic one, and models such as Nordhaus' DICE (Dynamic Integrated Model of Climate and the Economy)(Nordhaus 1993a) are explicitly designed to capture long-run trends over time. However, once the various paths have been specified showing expected costs and benefits over time, the cost–benefit approach reduces cost and benefit to single-value numbers in order to estimate the net present benefit of abatement effort. This is conventionally done using a discount rate, which means valuing costs and benefits less and less the further they lie in the future. This procedure is often defended by reference to the investment problem faced by an individual firm operating in an economy with a well-defined cost of capital that is outside the firm's control, so that profit-maximisation requires that the firm undertakes only those investments that perform better than the exogenously given market rate of interest. When the analysis involves the global economy as a single firm, however, this rationale for discounting falls away. The standard of reference for comparing the future to the present then is not an exogenous 'rate of return on capital', but a combination of two elements:

- the expected rate at which the global community expects to increase its wealth through time, with environmental capital included in the definition of 'wealth'; and

[5] An attractive feature of a carbon tax in this situation is that, because it provides an incentive for adoption of all abatement options that cost less than the tax, a tax set to drive economic agents to abate up to a marginal cost of $C_1$ in Figure 1 would in fact result in abatement effort at $T_3$ in Figure 2, so that technological progress which lowers marginal abatement cost is captured as additional abatement effort under a tax instrument. In contrast, a quota instrument such as tradeable permits would lead to abatement effort at $T_1$ in Figure 2, but with a market price of permits below $C_1$. (Some authors argue that a carbon tax, by raising the price of energy at an early stage, may itself be a means of inducing technological progress that shifts the marginal abatement curve down; see Grubb *et al.* 1993).

[6] On the economics of catastrophic outcomes see Collard (1988).

[7] This suggested formulation of an options model differs from that offered by Dixit and Pindyck (1994, pp. 412–418), who treat cost of abatement as the relevant investment project and argue for deferring action until proven damages reach a critical minimum threshold. From the point of view of the global community, it seems more appropriate to treat continued emissions as a deliberate disinvestment from the global stock of atmospheric capital, which should be halted until the known net benefits from increased emissions pass a threshold above the Marshallian level.

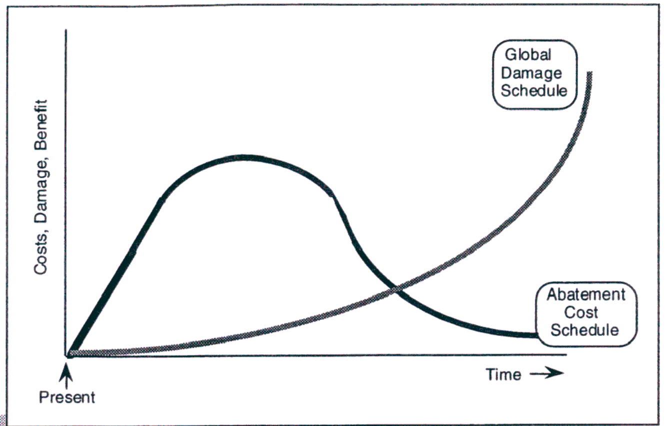


**Figure 3.** Hypothetical time paths of abatement cost and global damage

- the rate of pure social time preference (basically, whether the human race cares about future generations).

The contrast between numerical cost–benefit estimates using a positive discount rate and those using zero or negative discount rates is extreme when the time paths of costs and benefits are as shown in Figure 3. Here the costs of abatement come early and are transitional, as the global economy shifts to a sustainable energy base. The benefits of abatement rise over time, possibly becoming infinite at some distant future date if indeed the global ecosystem would collapse at a feasible level of cumulative emissions. Any finite probability of infinite future damage should technically dominate a cost–benefit calculation whatever the discount rate (since infinity itself cannot meaningfully be discounted), but for practical purposes no economic analysts are yet working with time scales beyond 300 years, and within this time horizon the discount rate is the crucial determinant of the net benefits of abatement. The bulk of empirical results to date use positive discount rates and accordingly produce conservative conclusions for policy. Work which uses zero or negative discount rates, not surprisingly, supports early and radical abatement effort.[8]

[8] The case for a zero social rate of time preference is made by Cline (1992, 1993a) and discussed in Pearce *et al.* (1994). The opposing view is put by Birdsall and Steer (1993). Cline argues that the discount rate should be the expected real growth rate of per capita world product, as a measure of the increased ability of future generations to bear the costs of global warming and/or abatement effort. An extension of this argument could include technological change to the extent that such change is exogenous to the economy and increases the ability of future generations to abate cheaply. Countervailing reductions in the discount rate would follow insofar as disinvestment in global environmental capital offset growth of real product per capita. Induced 'technology forcing' resulting from pro-abatement policy intervention would be taken account of as a downward shift of the abatement cost path in Figure 3, not through an adjustment to the discount rate.





## 'Top–down' economic modelling of abatement cost

Top–down economic modelling is suited primarily to the estimation of total abatement cost and permits the construction of estimated abatement cost schedules for the target economy, whether this is the world or a single country. Figure 4, reproduced from (Grubb *et al.*, 1993a,b), shows results from 13 global modelling studies. Total abatement cost for $CO_2$ abatement up to 100% (Figure 4a) is measured by the estimated proportion by which world GNP falls below the business-as-usual projection. Marginal abatement cost (Figure 4b) is measured in terms of the carbon tax, in \$ $t^{-1}$C, required to induce various levels of abatement effort in the absence of behavioural change or accelerated technological progress. For 60% abatement, typical top–down estimates of total cost are over 2% of world GNP, with marginal abatement cost generally over \$200 $t^{-1}$ C.

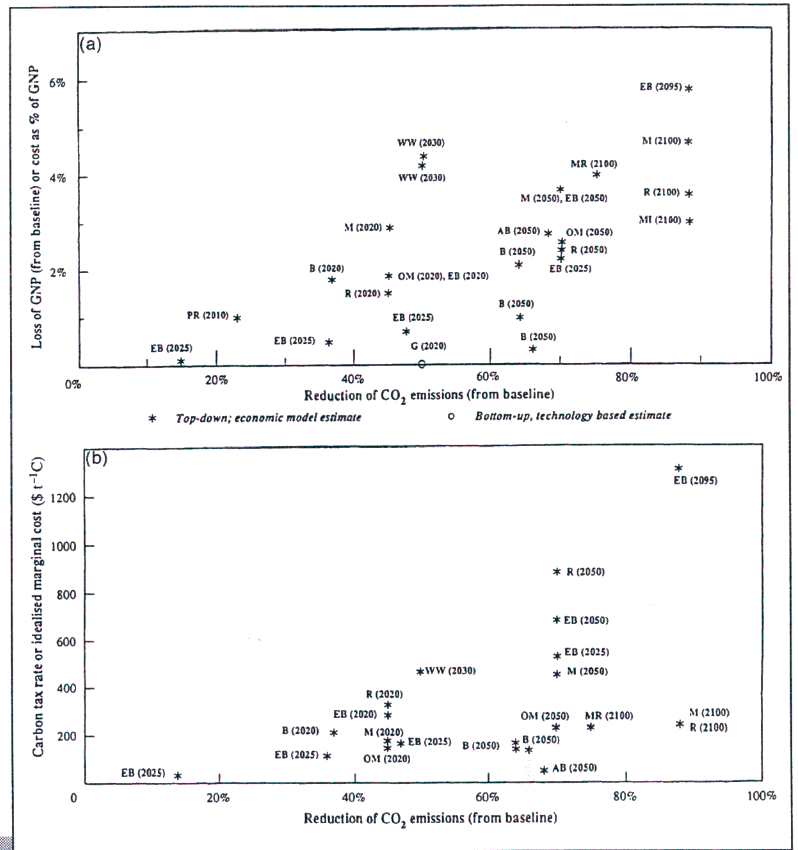


**Figure 4.** Results from 13 global abatement cost studies as presented in Grubb *et al.*, (1993) showing (a) total and (b) marginal abatement cost estimates. Each dot represents the outcome of an experiment with a computable general equilibrium model of the world economy.

Estimates of total and marginal damage have tended to give figures lower than these for the IPCC's one-off 2 × $CO_2$ scenario and for business-as-usual projections out to 2030. A cost–benefit approach to policy using these estimates yields cautious (low-abatement-effort) recommendations. Little work is yet available on global damage projections beyond the next century and/or the 2 × $CO_2$ benchmark.

Single-country modelling work aims to identify the total and marginal abatement cost schedules for one country, generally (but not always, e.g. the Tasman Institute's New Zealand work discussed below) using the assumption that the rest of the world continues with business as usual. Reasonably dense top-down and bottom-up modelling results for the USA are available (see Figure 5) which match the patterns sketched in Figure 1 for both total and marginal cost. Abatement up to 40% is estimated to cost a change of GNP of between +0.5 and –2% ; 60% abatement costs a reduction of 2–4% of GNP; and greater than 80% abatement costs 3–8% of GNP. Bottom–up studies give lower cost ranges, including a number of negative-abatement cost estimates for up to 55% abatement relative to business-as-usual.

For a single country, the total benefit schedule is extremely difficult to define because the relevant processes are global, not national. This means that the damage suffered by each country is experienced as an externality flowing from the world community's emissions, rather than a direct consequence of the country's own actions. For small countries such as New Zealand, a direct economic incentive to adopt abatement-promoting measures arises only insofar as the world community establishes a regime of carbon taxes, tradeable permits or trade sanctions that obliges all countries to internalise the global cost of their national emissions. At present, the incentive to act arises only from the political will to be a good global citizen and to abide by commitments made at the 1992 United Nations

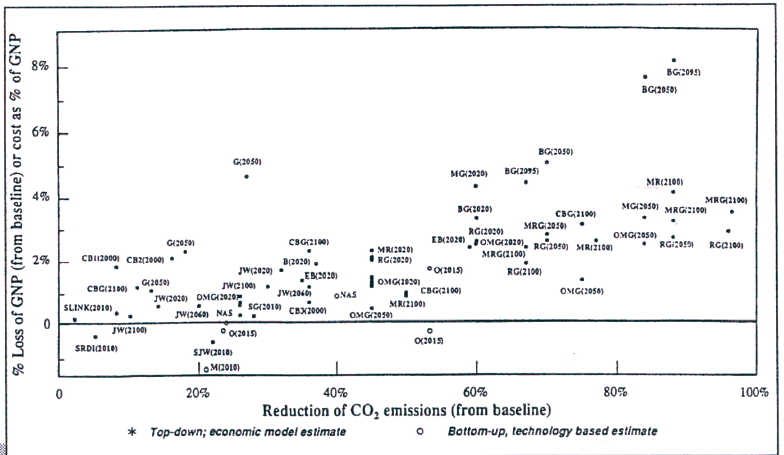


Figure 5. Results from US abatement-cost studies as presented in Grubb *et al.*, (1993). Each dot represents an experimental outcome from a computable general equilibrium model of the US economy when the model equilibrium is disturbed by imposition of a carbon tax.





Conference on Environment and Development in Rio. Beyond this, the incentive for New Zealand and similar small countries will be to free-ride until a global carbon tax or emissions market is established.

Commitments made at the Rio conference apply only to abatement within the next decade and are specified relative to a 1990 emissions benchmark. Modelling work for the New Zealand Government has therefore focused increasingly on the bottom left-hand end of the abatement cost schedule, while diplomatic effort has focused on securing acceptance of an interpretation of the country's abatement commitments in terms of net rather than gross emissions, which would reduce significantly the minimum abatement effort required to meet New Zealand's commitment. Once the target level of abatement effort is defined, the marginal abatement cost schedule then shows the implicit carbon tax rate which the world community has imposed on New Zealand via the Framework Convention on Climate Change.[9]

## Limitations of General Equilibrium Models

Before presenting the results of recent New Zealand modelling work, three limitations of the computable general-equilibrium (CGE) modelling technique (in the present state of the art) should be emphasised. The first is that CGE models have few, or no, dynamic feedback loops by which changes in prices and quantities can drive endogenous technological progress and investment behaviour. In the experiments reported here, therefore, business-as-usual prevails across all scenarios in terms of the rate of change of total factor productivity and the level of investment (and hence the capital stock in the model solution[10]).

The second limitation is that in modelling a small open economy, it is necessary to specify whether or not business-as-usual continues in the rest of the world, given that trading performance is an important determinant of output, employment and economic structure for such economies. As indicated, a world in which New Zealand has an incentive to abate is likely to be one in which some explicit or implicit carbon charge has been imposed, so that the rest of the world also has some incentive to adjust away from business-as-usual. Modellers can either ignore this effect (as we decided to do) or explicitly include it as the Tasman Institute (1992, 1994) do in most of their published experiments).

The third limitation, a vexed issue, is the question of how a general-equilibrium model should be 'closed'. Closure is the choice of certain fixed points around which the model solves its system of simultaneous equations. Where several alternative possible closures exist (as they always do) the modeller must opt for one, and in doing so may significantly affect the results obtained. In relation to the balance of trade, for example, there is a

9 Because country-by-country quantitative targets such as those set at Rio imply differences in marginal abatement cost from country to country, some sort of implicit trading arrangement—the embryo of a world market for carbon emissions—is likely to develop to reduce the resulting distortions. Proposals for 'joint implementation' and various international offset schemes point in this direction, and may in due course present New Zealand with positive economic incentives to increase its abatement effort with respect to gross emissions.

10 The sole exception is Run 59 in Stroombergen (1994) in which disinvestment in thermal electricity generation is counted as a capital loss to the economy.

choice between holding the economy's competitiveness fixed and letting the trade balance move into surplus or deficit; holding the trade balance fixed and requiring competitiveness to adjust accordingly; or fixing the nominal exchange rate and allowing both competitiveness and the trade balance to vary. (Our modelling work uses the third of these.) For the government sector, the modeller may hold government spending fixed and allow the budget deficit to vary, or hold the budget deficit fixed and require some component of taxes or expenditure to vary endogenously to maintain this balance. For the labour market, the alternatives are to hold employment constant and allow the real wage to vary, or to hold the real wage fixed and allow employment to change.

The importance of closure assumptions may be briefly illustrated with reference to government and the labour market, both of which are important in the results reported below. Because the 'shock' used in the experiments is a tax change (imposition of a carbon or energy tax), it is necessary to specify whether the additional tax is the only change made by government (in which case government revenue will increase, its budget will move towards surplus, and the private sector of the economy will be squeezed) or whether, alternatively, the government maintains 'fiscal neutrality' by changing some other component of its taxation or spending so as to keep total tax revenue, or the budget balance, unaltered from the beginning to the end of the experiment. Because tax increases have contractionary effects, failure to impose fiscal neutrality would lead to experimental results in which the abatement-cost effects of the carbon tax would be lost in the contractionary impact of a tighter fiscal policy.

Most greenhouse abatement modelling work now imposes fiscal neutrality, but this means that the carbon tax has to be introduced to the model as part of a total fiscal package of tax and/or expenditure changes, and the experimental results depend on how this package is constructed. A number of CGE studies have estimated zero or negative abatement costs for fiscal packages that include carbon taxes. That is, by imposing a carbon tax on the model economy but 'recycling' the revenue to reduce certain other tax rates, or to fund specified expenditure programs, it is possible to secure positive economic outcomes while reducing carbon emissions. Examples of this work are Shackleton *et al.*, (1992) for the USA and Barker *et al.* (1993a) for the UK. Of special interest in relation to some recent New Zealand results is the finding of Barker *et al.* (1993a) that a carbon tax used to offset Value Added Tax in the UK had a positive effect on GDP in his model. In interpreting these results, it is important to bear in mind that the economic benefits which they discover are attributable to the resource reallocation which follows from a restructuring of the tax base—not simply from any direct economically beneficial effects of a carbon tax.

In relation to the labour market there is a more difficult choice. In using a CGE model to produce 'long run' results, it is common practice to hold employment fixed between the business-as-usual base case and the experimental run of the model. This then requires the real wage rate (and hence the distribution of income between wages and profits) to vary so as to clear the labour market, while output is able to change only to the extent that the model identifies opportunities for capital, materials and energy to be substituted for labour in the sectoral production functions, and for changes in the composition of GDP to change the aggregate output/labour ratio. For a small open economy, this means that changes in international competitiveness as a result of a carbon tax can have only a limited impact on GDP (only substitution effects, no income effects) and are not allowed to have any effect on employment, which is determined by the fixed supply of labour.





An alternative specification is to hold the real income wage fixed (that is, to assume that wage negotiators will seek the same return to workers under business-as-usual and the experimental situation) and to allow employment to vary, implying either that there exists some reservoir of spare labour within the local economy, or that an increase in the availability of local employment at a given real wage induces in-migration of labour on a scale sufficient to make a significant difference.[11] New Zealand experience suggests that the second approach has plausibility in a long-run setting, and we adopted this closure for the labour market in most of our 1993 modelling work, attracting as a result strongly critical comment from peer reviewers who preferred the fixed-employment closure (Dixon *et al.*, 1994). Because the model results (especially those showing negative abatement cost) are sensitive to labour market closure, this area of debate needs to be borne in mind in interpreting them.

## New Zealand abatement cost modelling results

### *The Tasman and BERL/Fletcher-Challenge studies*

In New Zealand, the first full-scale attempt to estimate the effects of a carbon tax using an economy-wide CGE model was by the Tasman Institute (Tasman Institute 1992; Chisholm *et al.*, 1994), which found that New Zealand's GDP in the Australian Industries Commission's WEDGE model would fall 0.8% in the target year (2005) as the result of using a carbon tax to reduce emissions by 40% from the business-as-usual projection (Australian Industries Commission, 1991). Compared with the abatement costs estimated by WEDGE for the other OECD countries, this was quite a modest figure; only Japan exhibited lower costs of abatement than New Zealand in a multilateral emission-reducing experiment with the model (Tasman Institute 1992; p. 24, Table 4.2).

Interestingly ('counter-intuitively' according to the study authors) the New Zealand economy did better in a macroeconomic sense if a carbon tax was imposed unilaterally while the rest of the world carried on with business-as-usual than if all countries moved together to reduce emissions. The first two columns in Table 1 show the results of the two model runs reported in the 1992 study. It can be seen that when unilateral action was compared with multilateral action New Zealand's GDP, disposable income, consumption, exports and imports all fell less in the unilateral Tasman experiments; the two price indexes rose less; and the terms of trade improved rather than worsened.

The study authors pointed out that the essential difference between the multilateral and the unilateral scenarios was that when all countries act together to cut world emissions, with the OECD leading the way, the result in the model is a fall in world output and demand, so that part, at least, of the adverse effect on the New Zealand economy (column 1 of Table 1) reflects a fall in demand for New Zealand exports combined with an increase in the world price of New Zealand imports. In contrast, when New Zealand was modelled as acting unilaterally, import prices and world demand remained unchanged, so that the CPI rose only slightly and nominal wages actually fell, reducing New Zealand's loss of international competitiveness (Tasman Institute, 1992).

[11] In relation to the history of economic thought, this approach to long-run labour market equilibrium bears some resemblance to that used by classical writers such as Ricardo and Malthus, who assumed labour supply to be endogenously determined by the size of the wages fund at a given (subsistence) real wage.

**Table 1.** Tasman Institute modelling results: simulated impact of a carbon tax on the New Zealand economy

| | Tasman Institute (1992) Solution year 2005 | | Chisholm et al. (1994) Solution year 2000 | Chisholm et al. (1994) Solution year 2010 |
|---|---|---|---|---|
| | Multilateral action[1] | Unilateral action[2] | Multilateral action[3] | Multilateral action[3] |
| Percentage change in: | | | | |
| Real Net Domestic Product | –0.84 | –0.83 | –0.51 | –1.54 |
| Price index for NDP | 2.03 | 0.33 | 1.21 | 3.59 |
| Real national consumption | –1.08 | –0.92 | –0.73 | –2.17 |
| Real disposable income | –0.71 | –0.61 | –0.85 | –2.47 |
| Nominal wages | 0.98 | –0.74 | –0.21 | –0.53 |
| Consumer Price Index | 1.96 | 0.17 | 1.57 | 4.63 |
| Terms of trade | –0.09 | 0.34 | –0.15 | –0.39 |
| Volume of exports | –1.5 | –1.46 | –0.5 | –1.27 |
| Volume of imports | –1.74 | –1.29 | –0.78 | –1.96 |
| Emissions of $CO_2$ | –40 | –40 | –12 | –23 |
| Carbon tax US $t^{-1}$ $CO_2$ | 42 | 41 | 42 | 125 |

Sources: [1] from Tasman Institute 1992 (p. 24, table 4.2).
[2] from Tasman Institute 1992 (p. 36, table 5.1).
[3] from Chisholm et al., 1994 (p. 16, table 3).

The fact that the WEDGE model ranks unilateral ahead of multilateral action for New Zealand is a policy conclusion of some interest. The Tasman Institute results pointed to a possible case for New Zealand acting ahead of other countries, in order to sequence its domestic allocative adjustments ahead of the model's expected downturn in world economic activity as multilateral action is taken (something over which New Zealand's influence is very slight).

The next researchers were Fletcher Challenge and BERL, who used CERES, a new variant of the JULIANNE CGE model, to investigate the effect on the New Zealand economy of a unilaterally imposed carbon tax (Stroombergen and Miller, 1992). These modellers also found outcomes from a carbon tax that involved relatively low levels of abatement cost in terms of GDP. Achieving the Toronto target by unilateral action, they found, would require a higher tax than that estimated by the Tasman study (\$112–121 $t^{-1}$ $CO_2$ against the Tasman Institute's \$70 [US\$41 in Table 1]) and would produce GDP changes ranging from +2.3% to –2.0% depending on the labour-market closure and rate of technological change. A positive GDP effect was obtained by holding employment fixed and allowing the real product wage to fall, a process which more than offset the downward pressure of the carbon tax on economic activity. A fall in GDP resulted when the real product wage was held fixed and both employment and output were allowed to adjust. Not surprisingly, imposing an accelerated rate of technological progress into the model led to more favourable macroeconomic outcomes.

The study authors concluded that 'the changes in economic welfare as measured by private consumption or gross domestic product… are likely to be negative' (Stroombergen and Miller, 1992, p. 3). They focused also (as did Tasman Institute, 1992 p. 51) on the





dynamic costs of adjustment to a carbon-tax regime if the tax were imposed suddenly at year 0 (Stroombergen and Miller, 1992 p. 3, p. 55), suggesting that 'the transition costs in terms of lost output due to industry disruption are likely to be severe in the short run'.

These first two modelling studies raised several interesting questions from a policy point of view. The GDP losses that are usually cited as the main cost of emission abatement appeared modest, and (to judge from Stroombergen and Miller's Runs 4 and 7) very sensitive to the closure assumptions used in the modelling. The finding of a negative GDP effect (positive abatement cost) was thus not very robust. New Zealand appeared to require lower carbon taxes than many OECD countries to meet the Toronto target, and incurred lower costs if it acted unilaterally than if it was part of a multilateral effort.[12]

## *1993 Modelling for the Ministry for the Environment*

Bertram *et al.*, (1993a) used another JULIANNE-derived model, ESSAM,[13] to model a range of unilateral carbon-tax scenarios for New Zealand. This work was commissioned by the New Zealand Ministry for the Environment and carried out by Simon Terry Associates and BERL (STA/BERL). The structure of the model was the same as that of the CERES model used in Stroombergen and Miller (1992), but some adjustments were made to the database and some different closure assumptions were used.

The essential results are captured by four measures: energy intensity, $CO_2$ emissions, GDP and employment. Policymakers are assumed to be seeking to minimise the first two while maximising the other two. Various experiments with the model were designed to test which policy instruments gave the greatest progress towards energy and emission targets at the least cost in terms of output and employment for the economy as a whole.

The most striking feature of the results was a general absence of negative macroeconomic consequences from a carbon tax, so long as fiscal neutrality was maintained by 'recycling' the revenues from a carbon tax back into the economy via other tax reductions. Especially controversial (in terms of the later response from peer reviewers and government officials) was the finding that using a carbon tax to fund reductions in the rate of Goods and Services Tax (GST) would have an expansionary effect—something which several commentators interpreted as implying that GST was a 'more-distorting' tax than a carbon tax (TER, 1994, p.1; Infometrics, 1994).[14]

[12] Given the way in which the Tasman Institute results favour unilateral over multilateral action, it is unfortunate that in their recently published paper (Chisholm *et al.* 1994) they have given only multilateral results. Not only does this bias the reported results against a carbon tax, but it also leaves the authors open to misinterpretation when they present their results as the consequences of 'New Zealand adopt[ing] a policy of stabilisation of carbon dioxide emissions at 1990 levels by the year 2000' without adding the caveat that the rest of the world is modelled as adopting high carbon taxes which shrink world demand for New Zealand exports—possibly the dominant factor in explaining the results presented in table 3 of the paper (Chisholm *et al.* 1994 p. 16). To be fair, the abstract and other sections of the paper do make clear that the scenarios modelled are multilateral ones.

[13] Energy Substitution Social Accounting Matrix.

[14] This interpretation of the model results would be easier to sustain for experiments conducted with a fixed-employment closure assumption than in the STA/BERL work which leaves employment 'free' and thus allows income as well as substitution effects to flow through to the model results. Even with the fixed-employment closure it is necessary to adopt some strong assumptions before interpreting GDP changes in the model as evidence of changes in the deadweight burden of taxation.

Most of the experiments reported showed gains in GDP and employment flowing from improved international competitiveness. The main 'driver' in these results was the fall in the Consumer Price Index caused by the removal of other taxes—especially petrol excise tax—as carbon tax revenues were recycled. The labour market closure in most runs involved a constant real income wage (in contrast to the fixed real product wage used by Stroombergen and Miller (1992) to obtain their negative GDP result) and hence the nominal wage rate fell and competitiveness improved as carbon taxes were imposed.

Figures 6 and 7 present the key findings of the 1993 modelling program. Figure 6 shows the results of experiments in which a uniform carbon or energy tax was imposed on all carbon-emitting activities (mainly but not exclusively fossil fuel use) with the revenues used to eliminate the existing petrol tax and Energy Resources Levy.[15] This permitted an exploration of the amount of emissions abatement that might be achievable simply by reshuffling the existing tax take from the energy sectors. By imposing a carbon tax of \$33.60 $t^{-1}$ $CO_2$ (roughly \$120 $t^{-1}$ C) and thus shifting tax incidence off the very inelastic demand for petrol and onto the more price-responsive industrial demand for fossil fuels, the modellers were able to reduce carbon emissions by 15–20% below business-as-usual with no loss of GDP—indeed, the model showed a slight increase in GDP (negative abatement cost).

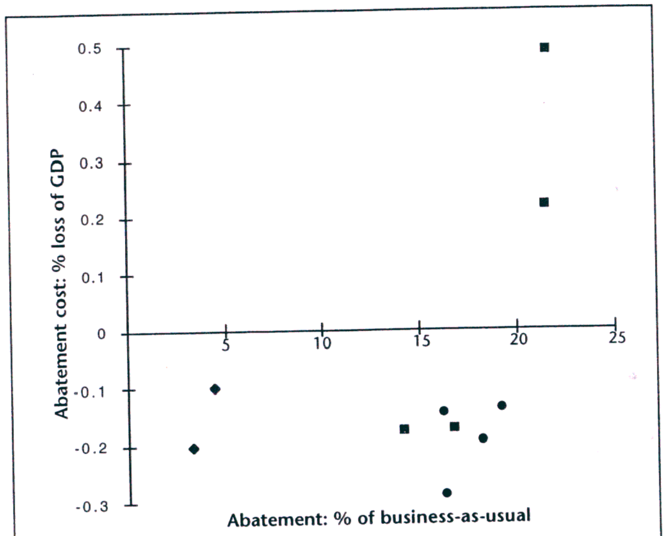


**Figure 6.** Economic impact of restructuring New Zealand energy taxation to a carbon tax or uniform energy tax, from Bertram *et al.*, (1993a). Model runs with a uniform energy tax (◆); results with a carbon tax of \$33 $t^{-1}$ $CO_2$ (●); and sensitivity experiments with an alternative specification for the electricity generation sector (■) are shown.

[15]The Energy Resources Levy is a wholesale tax on natural gas (45 cents $GJ^{-1}$) and coal (\$2 $t^{-1}$) which was introduced in 1976. (see Chapter 3 of Bertram *et al.* 1993b).





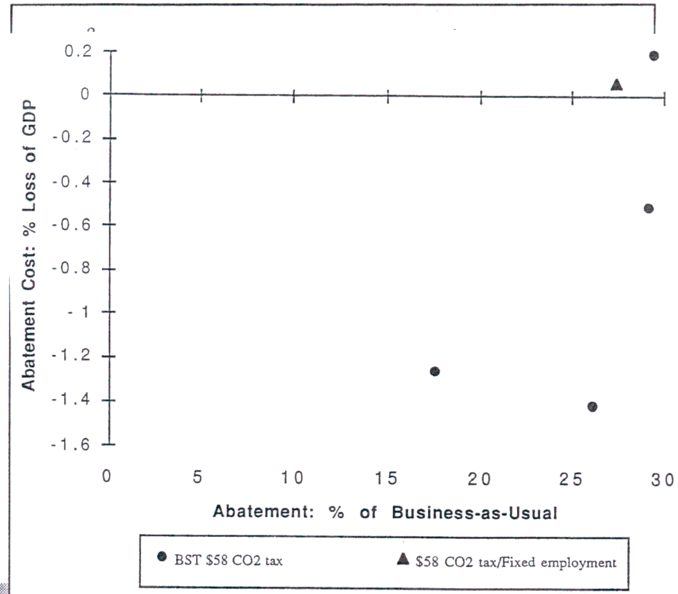


**Figure 7.** STA/BERL Results for Higher Carbon Taxes with Recycled Revenues

Source: Bertram, Stroombergen and Terry *[1993:61]*.

Use of a uniform energy tax (on a \$ per GJ basis) in place of the carbon tax dramatically reduced the effect on emissions, with no experiment achieving 5% abatement from business as usual. Under New Zealand conditions, therefore, the study points to the carbon tax as clearly the superior economic instrument for emission abatement, an interesting contrast to McDougall's (1993) findings for the Australian economy

Transition costs are not taken into account in the ESSAM model because of its comparatively static character, and have to be borne in mind as the main qualification to the conclusion that abatement cost for New Zealand up to perhaps 20% below business-as-usual over a ten-year period is negligible or possibly negative.

Figure 7 shows the results of imposing a carbon tax at \$58.20 $t^{-1}$ $CO_2$ (\$213 $t^{-1}$ C) with the revenues recycled by eliminating non-dedicated petrol tax and the Energy Resources Levy, and then using remaining excess revenue to reduce other tax rates: personal income tax, GST and corporate tax. Abatement cost (ignoring transition costs) is estimated as negligible or negative for emissions abatement of 20–30% below business-as-usual.

Given that the model identified no major abatement costs for the economy-with-carbon-tax equilibrium compared to business-as-usual, debate over the study findings focused closely on three issues:

- the technical details of model construction—especially the use of cross-price rather than Allen elasticities and the closure used (Dixon *et al.*, 1994);

- the difficulty of capturing accurately the effects of a carbon tax on some specific very large industrial operations such as Comalco, New Zealand Steel, and the Synfuels plant;
- the continuing absence of any dynamic or quasi-dynamic modelling results to show the transition path for the economy.

Subsequent work (Stroombergen *et al.*, 1994) suggests that the 1993 modelling results are robust with respect to cross-price versus Allen elasticities;[16] and that although sensitive to labour market closure assumptions, the results do not switch radically (e.g. from negative to positive abatement cost) if the labour market is closed by fixing employment rather than the real income wage, although the large employment gains obtained under the fixed-wage closure do not occur in the new runs, being replaced by a rising real wage. The dynamics of adjustment remain an area for more work.

The main problem identified to date as a result of sensitivity testing is in the specification of the model's electricity sector, which in the 1993 version of the model was a single sector with a single price, so that the impact of the carbon tax was spread across hydro generation. A number of alternative specifications have been tested (Stroombergen 1994) and it has been found that significant changes in the economy-wide abatement cost estimate can follow from the way the electricity sector is described. In particular, two runs in this series estimated abatement cost as positive rather than negative for the moderate, revenue-neutral $CO_2$ tax scenario shown in Figure 6. In these runs, the $CO_2$ tax was targeted entirely on marginal thermal plant, driving such plant out of the industry and creating losses for the economy as a whole as a result of the resulting disinvestment, especially if it was assumed that this abandonment of generation plant was a total loss from the economy-wide capital stock. This last case resulted in a 0.5% loss of GDP for 22% emission abatement.

The most recent modelling program, results from which became available in August 1994 (Stroombergen *et al.*, 1994), concentrates on very low tax rates of up to \$10 $t^{-1}$ $CO_2$, with abatement effects ranging from 1 to 5% reduction in emissions below business-as-usual. Employment was held fixed in most of these runs. Abatement cost continued to show up as negative, but falling real wages in most experiments indicated that the tax was having a contractionary effect, which came through as a fall in GDP when a sensitivity test was conducted that held the real wage fixed and allowed employment to vary.

Figure 8 shows the results of 51 model experiments in the three modelling programs carried out for New Zealand since 1992, and surveyed in this paper. Comparison with Figure 5 shows that the New Zealand estimates up to 30% abatement cluster lower than those for the USA to date, but that the range of estimates in the two economies is similar.

[16]Stroombergen (1994) section 5, pp. 16–18 finds that changing from cross-price to Allen elasticities yields marginally less favourable GDP outcomes but that the difference is only 0.1%. The elasticity of carbon emissions with respect to the carbon tax is also reduced somewhat but none of the conclusions of Bertram *et al.* (1993) is affected.





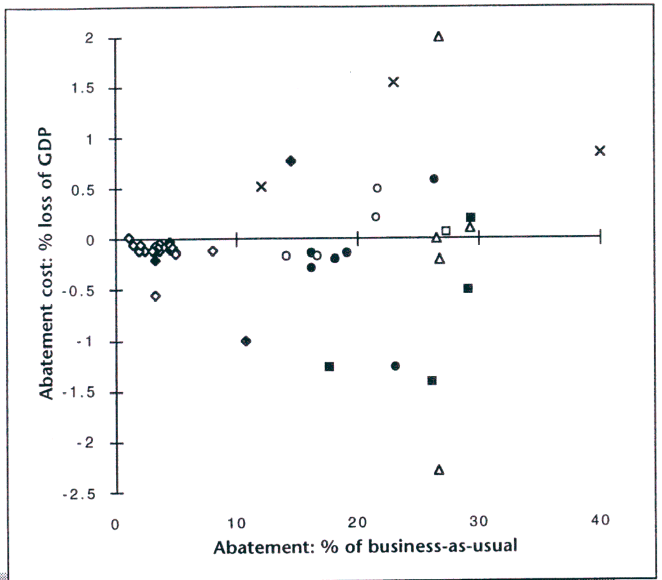


**Figure 8.** $CO_2$ abatement-cost estimates from New Zealand modelling to date.

× Tasman Institute experiments with $CO_2$ taxes (Tasman Institute, 1992; Chisholm *et al.*, 1994);
△ 1992 BERL/Fletcher Challenge results (Stroombergen and Miller, 1992);
● results with a \$33 $t^{-1}$ $CO_2$ tax;
○ shows sensitivity tests with an alternative economic specification of electricity generation, (Bertram *et al.*, 1993);
■ results with a \$58 $t^{-1}$ $CO_2$ tax;
□ shows a sensitivity test with employment fixed, from Bertram *et al.*, (1993);
◇ experiments with $CO_2$ taxes of less than \$10 $t^{-1}$ $CO_2$ (Stroombergen *et al.*, 1994).

## Competitiveness and Comparative Advantage

A significant point to emerge from the work commissioned by the New Zealand Ministry for the Environment over the past year is that in general equilibrium terms it is possible for a unilaterally imposed carbon tax to improve the competitiveness of the New Zealand economy. This proposition flies in the face of the intuitive argument commonly put forward by those energy-intensive industries which find their own profitability threatened by the prospect of a carbon tax; but in fact it is simply an illustration of the distinction between partial analysis (which considers a particular industry or firm in isolation on the assumption that other things remain equal) and general-equilibrium analysis which takes for granted that the entire set of prices and quantities prevailing across the economy will adjust in the process of moving to a new equilibrium once a carbon tax is introduced.

The ESSAM model indicates that the increase in the relative cost of energy inputs to industry as a result of a carbon tax may well be more than offset by a fall in the relative cost of labour inputs, leaving all but the most energy-intensive sectors in an improved competitive position. The fall in real labour cost occurs in the model because the revenue collected from the carbon tax is recycled in ways which improve the position of worker households at a given money wage rate, and hence enable wage bargains to be struck at a lower money rate than would prevail under business-as-usual.

The central requirement for this feedback to operate in reality lies in the design of the fiscal package in which a carbon tax is embodied. Provided that fiscal neutrality is maintained by appropriately recycling the carbon tax revenues, there is no need for the aggregate cost of production across the economy to rise, and there is therefore no need for competitiveness to fall. On the contrary, a gain in competitiveness is quite feasible.

There will nevertheless be losers and winners among the industrial sectors of the New Zealand economy. Industries which are labour intensive and non-energy-intensive, and those which have high substitution possibilities away from dependence on fossil fuels, are potential winners. Industries with inelastic demand for fossil-fuel energy, and a high proportion of costs accounted for by energy, stand to lose out competitively unless the world economy as a whole implements matching carbon taxes alongside New Zealand. This is a change not in economy-wide competitiveness, but in comparative advantage: a signal that it is appropriate for resources to be reallocated from those sectors where a carbon constraint will bite hardest, to those whose ability to compete internationally rests on advantages other than low-priced fossil fuels.

While it is clearly important for policymakers to take careful note of the problems of energy-intensive industries, especially during the transition to a carbon-tax regime, the results from general equilibrium modelling work provide a timely reminder that it is not necessarily the case that whatever is bad for New Zealand Steel, Synfuels and Coalcorp is bad for New Zealand as a whole.

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