Abatement: Global Action, Australian Road Transport, and Macroeconomic Costs

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Abstract -- The paper discusses the difficulties of obtaining cooperation among countries about measures to abate the Greenhouse effect, and examines efficient means of such abatement measures. It examines the generation of CO_2 emissions from fossil fuels in Australia, and analyses fuel efficiency and fuel taxes to cut emissions from road transport. Finally, it calculates the cost in terms of growth forgone of measures to attain the Toronto targets for Australian electricity generation and road transport.

Key word index: abatement; adaptation; CO_2; economic costs; fuel efficiency; greenhouse; road transport

1. CARBON DIOXIDE--THE KEY GREENHOUSE GAS

The setting

Toronto Conference The recent international conference of 46 nations held in Toronto resulted in a proposal to "reduce CO_2 (carbon dioxide) emissions by approximately 20% of 1988 levels by the year 2005 as an initial global goal" (Toronto Conference, 1988). So far Sweden is the only country to give legislative commitment to reaching the Toronto target. The objective of the present study is to examine options for Australia to achieve the Toronto target, and the likely costs involved.

The ultimate objective is not cutting CO_2 emissions at the individual country level or even globally, but rather to delay the onset of the greenhouse effect on climate and global warming. Focus on CO_2 is justified, however, as it is the most significant greenhouse gas, and others--notably methane (CH_4) and nitrous oxides--will be much more difficult to contain. Chlorofluorocarbons are already subject to international control.

The Greenhouse effect As Schelling (1983, p. 449) points out, the real concern is with climate and climatic variation rather than CO_2 *per se.* Climate change and its effects remain largely unpredictable (although understanding of medium-term effects, such as the "Southern Oscillation", is advancing rapidly). Some areas may benefit from higher rainfall, while other areas may suffer a reduction in rainfall, for example, as part of higher global temperatures. Parts of Australia may, for example, become wetter (CSIRO, 1987) with up to 50% more summer rain (see Walsh, 1989). Plant growth generally and certain crops in particular may be encouraged by higher concentrations of CO_2, as photosynthesis is encouraged by the greater presence of CO_2 (Waggoner, 1983). Schelling (1983) points out that the existing temperature zones on the inhabited portion of the planet show far greater variation than could be expected from the Greenhouse effect. In assessing the social welfare costs (or benefits) of climatic change, it must not be assumed that land use and human populations will remain static. They will not be locked into existing use and locations for ever.

Note: The following is a summary of Chapters 2, 3, 5, 6, and 7 of the report, "The feasibility and implications for Australia of the adoption of the Toronto Proposal for carbon dioxide emissions", (Marks et al 1989), Melbourne, CRA Ltd., September 1989. For a summary of Chapter 4, see McLennan (1990, this volume); see also Dixon and Johnson (1990, this volume).

The period over which the earth has time to adjust to climatic warming will greatly affect the extent of social welfare costs due to the Greenhouse effect. Studies of past climatic changes indicate that sudden increases or decreases in temperature can have highly disruptive and deleterious effects. The problem will be to assess where regional effects are likely to occur, and their severity. Where irrigation or other means can be used to adapt farming practices to the climate, the effects will not be so adverse (Waggoner, 1983). Of course, effects on natural ecosystems cannot be ameliorated.

Another worrying aspect of the Greenhouse effect for most people is the prospect of rising ocean levels, with resulting flooding of exposed coastal areas. Recent studies predict a rise in the sea level by 2030 of between 0.20 and 1.40 m (Walsh, 1989, p.16). To place this highly uncertain estimate in perspective, it is just as well to keep in mind that the sea level has risen 150 m in the last 150 centuries, following the peak of the last glacial period. The present rate of rise of between 0.1 and 0.2 m/100y is small compared with the average rate of 1 m/100y (Revelle, 1983, p.433) (although some people forecast Greenhouse-induced rises of up to 1 m/100y).

It should not be assumed that rising sea levels need necessarily have catastrophic effects when dykes, levees, land-fill or sea-fill can be used as defensive measures. For well-to-do built-up and densely populated areas, it may be cost-effective for sea rises of 5 or 6 m to build dykes, as the Dutch have done (Schelling, 1983, p.473). The situation is quite different in poor, low-lying countries, such as Bangladesh, where there is little, if any, prospect of protecting the huge coastal area, which is already subject to inundation.

World energy and carbon dioxide production

Data in Williams (1989), showing per-capita emissions of CO_2, put Australia in a particularly unfavorable light. Australia has the fifth highest emission, at 3.9 t/y of carbon per capita, compared with a world average of 1.0 t/y. The high per-capita emission is partly accounted for by Australia's comparative advantage in energy-intensive industry, the abundant availability of coal, including brown coal with a high CO_2 emission rate, and our relatively small population. Australia's high proportion (41%) of energy supplied from coal is exceeded only by China's. Not surprisingly, both countries have abundant coal reserves, with Australia one of the world's major exporters of coal (Marks, 1989).

Examining energy production on a per-capita basis can be highly misleading, especially since Australia is a major exporter of energy-intensive products: our emissions reflect the energy consumption of much of the rest of the world. Australia's share of the world production of CO_2 of 4.747 GtC/y is only 1.2% (Clarke, 1989); on this basis Australia's contribution is close to negligible. It is certainly negligible in the sense that unless Australia's policies can directly or indirectly affect CO_2 emissions from other countries, whether or not Australia is able to reduce its rate of CO_2 emissions will make a negligible difference to the world total and hence to the greenhouse effect. This emphasizes the obvious point that Australia alone can do little if anything to ameliorate the greenhouse effect.

Australia's ability to influence the Greenhouse effect

Before we ask what Australia can do to influence the world emission of CO_2, it is just as well to ask the prior question: what can the United States as the world's largest emitter of CO_2 do without world-wide coöperation? Edmonds et al (1989, p.41) point out that between 1950 and 1985 the US share of global fossil fuel emissions has fallen from 40% to about 22%. Emissions fell absolutely between 1980 and 1985, owing largely to the delayed impact of the first oil shock, since deregulation of energy US prices did not occur until the late 1970s, and to the second major oil price shock in 1979–80. It took a massive rise in the price of fossil fuels, and oil in particular, to bring about the actual decline in CO_2 emissions.

Holding US emissions constant at 1985 levels would represent a 28% saving relative to base-case estimates of emissions for 2010. Putting aside indirect effects of US emission reductions, such a major effort on the part of the USA would only have a 6% effect in terms of a global reduction in CO_2 if global emissions continue to grow (Edmonds et al, 1989, p.41). This reduction is only relative to the higher forecast emissions. What is worse, as Edmonds and Reilly (1983) point out, action in the USA to restrain the use of fossil fuels will have a drastic downward impact on the prices of fossil fuel in the rest of the world. This depressing effect on prices would, everything else equal, result in even greater usage of fossil fuel in the rest of the world, with higher CO_2 emission than otherwise. Technological improvements made in the USA could act in the other direction, especially if they were adopted by other countries.

If it is hard for the world's largest CO_2 emitter, the USA, acting unilaterally, to have a significant impact for the better on CO_2 emissions, then it is clearly virtually impossible for Australia. Recall that Australia, unlike the USA, is a negligible contributor to the Greenhouse effect on a world scale. Sometimes the argument is put this way: the saving of emissions of one Australian enables 10 Chinese, or 50 Indians, to double their current rate of release without adding to the Greenhouse problem (Williams, 1989). While factually correct, such an argument is not very helpful in the context of populations which exceed Australia's by well over a hundred-fold. The problem is intensified by the fact that both China and India are embarking on a considerable expansion in power and hence CO_2 emissions. While the base from which they begin is low, the potential exists for both countries to rival industrialised countries in terms of CO_2 emissions in the not-too-distant future. Perhaps Australia's efforts ought to be directed at assisting S.E. Asia, China and India not to add to the Greenhouse problem, perhaps by exports of more efficient energy-generating and -consuming technologies.

Constraints on action--the Prisoner's Dilemma There is a powerful metaphor which casts light on what can be done about excessive emissions of a collective or public "good" or, more aptly, "bad". CO_2 is consumed collectively by all inhabitants of the earth in terms of the Greenhouse effect, regardless of where the emissions originate or even why the CO_2 was discharged. This metaphor is known as *the Prisoner's Dilemma.* Suppose that a thief and his accomplice are caught and interviewed in separate cells. If neither prisoner confesses, they will each get off relatively lightly. If one turns Queen's Evidence and identifies his accomplice in the neighbouring cell, he is discharged without penalty while the accomplice is severely penalized. If both confess and incriminate their accomplice, then both serve long prison sentences.

Unless there is severe underworld retribution combined with "honour among thieves", both prisoners will be led to confess and at the same time incriminate their accomplice. The analogy with the Greenhouse problem now becomes clear: had both prisoners been able to hold their tongues, that is, coöperate, then all would be well. Neither would pay a severe penalty. In the same way, it is in Australia's interest (we assume for the moment) to coöperate with the other prisoner--the rest of the world--and for both to individually ameliorate their CO_2 emissions. In this way the Greenhouse effect is either prevented or at least postponed. But it is in the nature of the Prisoner's Dilemma that the collectively rational action is unlikely to happen. Australia incriminates the rest of the world via its CO_2 emissions while the rest of the world does the same to Australia.

In fact, the problem is even worse than it appears here. Instead of the world being divided into Australia and the rest of the world, it is in fact divided into many countries. None of these countries unilaterally can have a great impact on the global emission of CO_2. Coöperative behaviour would in fact be more likely if the world were divided into two national blocs, each emitting the same quantity of CO_2. With two major players of this kind, strategies could be devised that might lead to continued coöperation in terms of reductions in CO_2 emissions.

An example of such a strategy is tit-for-tat, in which national bloc A adopts measures to reduce emissions in round one. If bloc B follows suit, then coöperation ensues. If bloc B fails to coöperate by restraining its emissions, then bloc A follows suit. A coöperative stance by bloc B is followed by a likewise coöperative stance by bloc A. A variety of computer tournaments (Axelrod, 1984) suggests that tit-for-tat strategies can be successful in two-player games under a fairly wide variety of conditions.

Certainly, when examined from a game-theoretic perspective, the prospects for world-wide coöperation in terms of all countries making and abiding by costly plans to reduce CO_2 emissions do not appear all that promising.

Split of interests between developed and developing countries. The split between the developed nations with high per-capita emission levels and the developing nations with modest emission levels per capita but with huge populations and in the case of China, large coal (fossil fuel) reserves, makes it doubly difficult. Naturally, the developing nations plan to make use of fossil fuels to emulate the industrialised west and to gain the same massive advances in living standards.

Uncertainty on Greenhouse effect. Despite heightened scientific interest and curiosity, there is still a great deal of uncertainty about when and how severe the Greenhouse effect is likely to be. Non-scientists are going to dismiss it in much the same way as fears of a new ice age were dismissed by the general public a few years ago. More sceptical members of the general public are likely to dismiss "alarmist" predictions or scenarios of catastrophic Greenhouse effects on the grounds that research funding is likely to be increased if the threat is perceived to be both severe and not far away.

Some regions may benefit anyway. Scientific evidence does seem to admit the possibility that at least some regions or at least some countries may be beneficiaries of warmer climates and more rainfall, at least for a while. Although it is by no means certain that there will be any clear-cut or "on balance" winners, the very possibility of some regions gaining, at least for a while, make it more difficult for all regions and countries to act coöperatively in terms of reducing CO_2 and other Greenhouse gas emissions. Each likely winner will argue: why should we incur large costs and falling living standards now, merely so that we can be denied the advantages of a warmer and wetter climate a few years into the future?

Abatement and adaptation strategies

It is possible to think about policies to deal with global warming in two distinct ways: abatement or adaptation. The first approach is exemplified by the Toronto Conference approach designed to mandate reductions in CO_2 emissions. The aim is to *prevent* the rise in global temperatures. The second strategy is to *adapt* to rising temperatures or, in other words, to attempt to cure any ill effects of higher global temperatures, supposing that they eventuate.

It is a truism to state that the more certain and serious the possible outcome, and the cheaper and more efficacious the available policies, and the greater the likelihood that harm is irreversible, then the greater the preference for preventative policies over adaptive policies (Portney, 1989 p.85). Clearly, some reductions in CO_2 emissions will come about relatively cheaply as a result of technical advances or cheapening renewable energy sources. These improvements should be adopted almost come what may: their adoption may have little to do with the Greenhouse effect. Similarly, energy conservation which can be achieved readily with the simple provision of additional information should come about anyway, regardless of the Greenhouse effect.

Once policies have been adopted at little cost, a more serious choice has to be made: should more expensive policies be adopted to switch from fossil fuels with high CO_2 emissions per unit of energy provided to those with less--for example, from brown coal to black coal and natural gas--or should fossil fuels generally be discouraged in favour of nuclear or renewable energy sources which may require large subsidies to compete with fossil fuels? Finally, large price rises for fossil-fuel-intensive final goods or fuel inputs may be required to induce consumption away from goods or services produced which require fossil fuels.

If the harm produced by rising temperatures is not all that serious, then the justification for incurring high costs now as part of an abatement strategy will be lacking. Schelling (1983), for example, considers that one of the main effects would be a loss of income from agriculture but that, with continued productivity improvements in agriculture and its declining importance in global Gross National Product (GNP), any consequences would be relatively minimal. These views are shared by Crosson (1989, p.76), who is even more optimistic that the effects will be minimal with a doubling in concentration of CO_2 dioxide. He is doubtful, however, that a global consensus will be easy to obtain, unless the doubling of CO_2 concentration has a sufficiently large impact on rising sea levels to reduce the growth in global GNP significantly.

Portney (1989, p.87) speculates that a lot of the fears about CO_2 emissions and temperature rises may simply be an irrational preference for the *status quo ante.* Suppose global temperatures rise, with certain regions such as parts of the USSR and Canada benefiting from the higher temperatures. Would the world then be willing to submit to a global cooling to bring the world back to present temperatures? The world at that stage may look back on the present time as akin to a mini-ice age and be unwilling to return to what for us is the *status quo.* Likewise, it would be hard to convince policy makers today to return the world to colder temperatures experienced earlier this century.

The fact that there will be gainers as well as losers from higher temperatures and the possibility that our desire for the maintenance of present world temperatures is but an irrational preference for the *status quo,* and a fear of the unknown may provide a justification for placing less emphasis on abatement policies and more emphasis on minimising the costs of adjustment to higher temperature levels. The enormous difficulty of gaining international coöperation and coördination among all the world's nations may force adaptation strategies on us even when we would prefer to use abatement policies.

The simple economics of abatement policies

CO_2 emission abatement policies in response to the Toronto Conference recommendation could take several forms, namely,

- a mandated 20% reduction in CO_2 levels in each activity and in each region of Australia;
- as above, but with tradeable emission quotas so that the costs of reducing the output of CO_2 are equalised over all activities producing CO_2; or
- a Pigovian CO_2 tax, such that each tonne of CO_2 emitted from any fossil fuel source is penalised at the same rate. (A Pigovian tax could be represented as so much per tonne of CO_2 emission or as so many dollars per black coal tonne equivalent.)

The first method clearly sounds the simplest to implement. It could also be the most expensive. The requirement of a simple quota reduction in CO_2 dioxide, such as the Toronto 20% reduction, will act like a Pigovian tax but with effectively different shadow tax rates, depending on the nature of the product or the area in which the CO_2 reduction is required. The inter-fuel substitution required to meet mandated CO_2 emission reductions will increase costs and hence prices of the products of services supplied.

Similarly, the most decentralised system of abatement control is a differential levy on fossil fuels and other sources of CO_2 in proportions which effectively penalise all emissions of CO_2 (and other Greenhouse gases, for that matter) at the same rate. As with tradeable emission quotas, if adjustment is expensive in Tasmania, the electricity authorities might simply choose to pay slightly more for black coal rather than make exceedingly expensive adjustments. In Victoria the levy on brown coal would be higher, forcing that state to turn to Oaklands or New South Wales for black coal or to burn more gas in fuel efficient ways. The proceeds from a Pigovian levy on CO_2 emissions could be used to reduce income and other taxes generally.

Seidel and Keyes (1983), Nordhaus and Yohe (1983), and Scott al. (1989) have considered taxes on CO_2 emissions. The first would tax shale oil at 100%, black coal at 52%, oil at 41%, and natural gas at 29%, reflecting the relative CO_2 intensities of the fuels. They found that a coal ban would not be effective if it accelerated the development of shale oil, and it would have other dramatic (and undesirable) effects. A general finding was that if taxes are increasing and sufficiently severe and applied globally, then they can be quite effective at eventually reducing global CO_2 emissions.

2. *ENERGY-RELATED CARBON DIOXIDE EMISSIONS IN AUSTRALIA*

Oxidation of fossil fuels releases heat, but also produces oxides of carbon (CO_2 and CO) and hydrogen (water). The biomass renewables of wood and bagasse--the spent, dried stalks of sugar cane--as hydrocarbon fuels also produce oxides of carbon when burnt. We shall assume that combustion is complete, so that all carbon is vented in the form of CO_2.

The combustion of renewable biomass results in a positive net flux of CO_2 into the atmosphere if the annual crops are dwindling in mass, and vice versa. It is likely that the net flux from Australian bagasse is about zero, but that continued clearing with no widespread reforestation results in a positive flux from fire-wood. CH_4 produced in the guts of animals also adds to the greenhouse effect, but to the extent that it comes from atmospheric carbon fixed by pasture grasses there is equilibrium in the carbon cycle, although CH_4 is more effective at trapping radiant heat than is CO_2.

The most recent energy-balance figures for 1987/88 enabled us to calculate the amounts of CO_2 being produced from combustion of fossil fuels in Australia (Table 1), given the thermal energy equivalents of the fossil fuels (ABARE 1989). (We found that the renewables, wood and bagasse, contributed 13.2 Mt/y of CO_2 emissions in 1987/88, or 5% of the emissions from fossil fuels.)

TABLE 1. Australia--direct and indirect emissions of CO_2 (Mt/y) by end use sector and by fossil fuel--1987/88.

	Black Coal	Brown Coal	Oil Products	Natural Gas	Total Direct	Electr-icity	Grand Total	*Share (%)*
Agriculture & Mining	0.7	0.0	5.8	4.1	10.6	9.1	19.7	*7.5*
Industry	21.8	1.3	11.1	17.2	51.4	47.5	98.9	*37.7*
Transport	0.4	0.0	73.0	0.0	73.4	1.5	74.9	*28.5*
Commercial	0.5	0.2	0.8	1.8	3.3	23.5	26.8	*10.2*
Residential	0.1	0.0	1.3	4.8	6.1	35.9	42.1	*16.0*
Total direct	23.5	1.5	92.0	27.9	144.9	117.4	262.4	*100.0*
Share (%)	*16.2*	*1.0*	*63.5*	*19.3*	*100.0*			
Electricity	69.2	38.3	1.7	8.3	117.4			
Share (%)	*58.9*	*32.6*	*1.5*	*7.1*	*100.0*			
Grand total	92.7	39.8	93.7	36.2	262.4			
Share (%)	*35.3*	*15.0*	*35.7*	*13.8*	*100.0*			

The electricity generation sector is a large source of emissions (44.7%), relying as it does on black and brown coal for 84% of its energy inputs. Any success in CO_2 abatement in this sector will be significant in Australia's emissions overall. (See McLennan, 1990, this volume, for a discussion of techniques and costs for reducing emissions from this sector.)

A second large source of CO_2 emissions is transport, which relies to an overwhelming extent on liquid hydrocarbon fuels as energy inputs. Road transport consumed the equivalent of

761.0 PJ/y of petroleum products in 1987/88, to produce 58.4 Mt/y of CO_2 emissions (22.3%), when refinery losses are pro-rated. The balance of emissions (33.0%) came from other energy conversion and from other end uses. In particular, industrial energy use produced 51.4 Mt/y of CO_2 emissions from the direct use of hydrocarbon fuels and 47.5 Mt/y indirectly from its electricity use (160.3 PJ/y or 47.4 TWh, including conversion losses) in 1987/88.

There are five ways in which Australia could reduce these emissions:

(1) By capturing or scrubbing the CO_2 from the exhaust and flue gases, but this--although technically feasible for some processes--would be prohibitively expensive for most processes, and certainly more costly than alternative measures.

(2) By substituting lower-carbon fuels for the high-carbon fuels now in use, such as brown and black coal. The use of hydro-power or nuclear-generated electricity would produce no CO_2, but there are other potential environmental problems with these fuels, and at the moment we could not readily substitute these sources for the petroleum produced used in road and air transport. Nonetheless, a move towards natural gas, which currently supplies 18.1% of the country's thermal energy and 13.8% of its energy-related CO_2 emissions, or towards the renewable energy sources would enable Australia to continue using energy at the same or growing levels with lower net emissions of CO_2.

(3) By moving to machines, buildings, and industrial processes which produce the same services with lower energy inputs; that is, to engage in greater levels of energy conservation.

(4) (More drastically): by actually cutting back on the levels of economic activity per person, so that outputs, energy inputs, and CO_2 emissions are all cut. The cost of cutting CO_2 emissions by curtailing end-use activities, such as freeway speeding, is much greater than allowing substitution to occur between, for example, an electric hot-water system and a solar system.

(5) (Ultimately): by reducing our rate of population growth, which might--other things equal--allow us to increase our per-capita energy use and CO_2 production, while reducing aggregate production of the gas.

Given the advances of technological knowledge, there is always a lag in the implementation and availability of energy-saving techniques, and given the durability of the stock of energy-using equipment, there is a further gap between average energy efficiency and the higher levels of energy efficiency of new equipment. Despite the availability of new, economically viable techniques for energy substitution and conservation, some observers have claimed that consumers--whether households or companies--are not taking advantage of these techniques by investing in new equipment to save both money and energy, and hence to reduce CO_2 emissions.

The economist is wary of claims that there exist unappropriated rents. The wariness is higher in cases of firms in competitive markets apparently ignoring such opportunities, and lower when knowledge of energy-saving possibilities is costly to acquire and when potential savings are a small proportion of total costs. Whether cost-effective or not for individual households or firms, the problem remains for society to induce a change in individuals' and organizations' behavior: to use "cleaner" fuels, to invest in more energy-efficient equipment, to cut back on end-use activities, or some combination of all three.

3. ROAD TRANSPORT

As seen from Table 1, the transport sector generated 74.9 Mt/y of CO_2 emissions in 1987/88, 28.5% of total emissions from fossil fuels. ABARE (1989) figures show that road transport fuel consumption was 79.3% and air transport fuel consumption was 11.2% of total transport fuel consumption of 959.9 PJ/y in 1987/88.

Two scenarios for road transport fuel

Base-case projections Using a commercial model for motor gasoline (petrol) consumption, with base-case assumptions about the macroeconomic environment (see Table 2), we have derived base-case projections for road fuel use through 2005. In the Base Case the consumption of motor gasoline (mogas) grows at an average annual rate of 1.78%, while consumption of diesel and LPG grows at 3.0% p.a., implying an income elasticity of 1.0. This implies an average growth rate of 2.12% p.a. for total road fuel. The base-case assumption of a 0.7% p.a. improvement in fuel efficiency would result in the total fleet average fuel efficiency improving from about 13.6 L/100 km in 1988 to 12.1 L/100 km in 2005. We see in Table 3 that from 57.3 Mt/y of CO_2 emissions in 1988, the base-case projection results in 82.3 Mt/y of CO_2 emissions in 2005, an increase of 43.6% above 1988. But the Toronto Agreement target is a 20% reduction by this date.

TABLE 2. Base-case projections of fuel use in transport--major assumptions--annual average percentage growth.

	Assumed 1989–2005	Actual 1980–1988
Population	1.4	1.4
Real Gross Net Expenditure	3.0	3.3
Real Gross Domestic Product	3.0	3.7
Consumer Price Index	5.0	8.3
Real new passenger vehicle prices	0.0	1.7
Real motor gasoline price	0.0	0.0
Passenger vehicle fleet average fuel efficiency improvement	0.7	0.7

High-efficiency scenario In the high-efficiency scenario we examine how effective the improvements in fuel efficiency outlined below would be in reducing fuel consumption and hence in reducing CO_2 emissions. We chose these particular improvements because they are the most optimistic projections of efficiency and costs with existing technology available.

Goldemberg et al (1988, p. 460) discuss potential fuel efficiency improvements possible today, at a total cost of over 25% of the unimproved cost of new passenger vehicles. We assume that the following improvements will progressively be introduced to new vehicles: all new vehicles diesel-powered, tyre rolling resistance reduced, reduction in aerodynamic drag to (0.3), from pre-chamber to open chamber diesel, from manual transmission to continuous variable transmission (CVT) 5:1, weight reduction, extended range of CVT (10:1), engine-off during idle and coast (for details, see von Hippel and Levi, 1983). These would increase the average fuel efficiency of the new vehicles from 11.0 L/100 km in 1988 to an extreme of 4.6 L/100 km in 2005, an extraordinary reduction, if it occurred. We assume that the fuel-efficiency improvements are progressively introduced in new vehicles over the sixteen-year period 1989–2005; so the cost of new vehicles progressively rises over this period to a maximum of 25% above the base case. The effects of these improvements on energy use and CO_2 emissions are shown in Table 4.

In this scenario we assume that real new passenger vehicle prices rise at 1.3% p.a. instead of zero as in the base case, as a result of the embodiment of fuel-efficiency measures which result in an average fuel efficiency improvement for the passenger vehicle fleet of 1.7% p.a. instead of 0.7% p.a. in the base case. The commercial model predicts an increase of mogas consumption in this scenario of 0.73% p.a. In addition, we assume that the consumption of diesel and LPG grows at 1.3% p.a., which implies an average growth rate of 0.88% p.a. for total road fuel. We see in Table 3 that this scenario projects CO_2 emissions of 66.6 Mt/y in 2005, an increase of 16.2% over 1988 emissions. In this scenario, the assumption of 1.7% p.a. improvement would result in a figure of 10.2 L/100 km in 2005 for the total vehicle fleet.

Price effects on transport fuel use To reduce fuel use and hence CO_2 emissions further the Report considered increasing the price of fuel. Using a conservative OECD estimate of long-run own-price elasticity of demand for transport energy of between 0.3 and 0.6 (IEA, 1987, p.46), we see that to reduce demand by 10% would require prices to rise by between 16.7% and 33.3%.

The Toronto target for CO_2 emissions of 20% below the 1988 level is 45.8 Mt/y. This would require a reduction of 44.4% from the Base Case, or 31.2% from the High Efficiency Scenario. To attain this reductions from higher prices, given a price elasticity of demand of between 0.3 and 0.6, would entail price rises of between 84% and 169% by 2005 for the Base Case, or between 62% and 123% by 2005 for the High Efficiency Scenario. These increases translate to between 3.6% and 5.8% p.a. for the Base Case, and between 2.8% and 4.7% p.a. for the High Efficiency Scenario. These results are summarised in Table 3.

TABLE 3. Scenarios for road transport CO_2 emission abatement.

	Fuel Energy (PJ/y)	CO_2 Emissions (Mt/y)	Emissions ÷ 1988 (%)
1988 Actual	783	57.3	Base
2005 Base Case	1,124	82.3	+43.6
2005 High-efficiency scenario	910	66.6	+16.2
2005 Base Case with fuel prices rising at 3.6%−5.8% p.a.	626	45.8	−20
2005 High-efficiency scenario with fuel prices rising at 2.8%−4.7% p.a.	626	45.8	−20

4. *ECONOMIC GROWTH FORGONE*

To estimate at the national level, the costs of cutting CO_2 emissions, we have used the ORANI economic model (Dixon and Johnson, 1990, this volume). The model simulates the effects of changes in prices which are required for the Greenhouse adjustments. We start with a base case projection for the economy (set out in Dixon and Johnson and summarised in their Table 1, p.??) and assess impacts on projected outcomes of, successively and separately: changes in electricity prices, changes in road transport prices, and reduction in export coal prices. In this section we focus on the effects on the growth rate of real GDP, as the primary measure of economic welfare. The Report (Marks et al 1989) also considers the impacts on real wages and private consumption.

Results of the ORANI simulations

As the figures in Dixon and Johnson (1990, this volume, Table 2, p. ??) reveal, the effects on the base case growth of Gross Domestic Product (GDP) of a 1% p.a. increase in the growth of real electricity costs depend on whether the costs are rising because of an increase in the input requirements per unit of electricity generated or because of an increase in taxation. Increased inputs will have a more serious effect on the growth rate of GDP than will taxation, because the tax revenues are not dead-weight loss, but rather represent a transfer of resources in the economy.

ORANI, in Dixon and Johnson (1990, this volume, Tables 2, 3, 4, and 5), provides linear approximations to the dead-weight losses as a function of changes in the rate of change of costs or prices. For a linear demand function, the dead-weight loss associated with a tax is a quadratic function of the change in price. For small changes in the rate of change of price, these linear approximations are probably close to the true growth effects, but for large changes, the approximations may well underestimate the true growth effects and hence the true dead-weight losses.

Forgone economic growth

In order to put a dollar value on the dead-weight losses, in each case, for two discount rates (5% p.a. and 10% p.a.) we calculate the difference between the present value of seventeen years of growth of GDP at 3.44% p.a. from 1987/88, when Australia's GDP was $295,018 million (RBA, 1989, p.S67), to the year 2004/05, when ORANI projects a GDP of $529,449 million in 1989 dollars, and the present value of these seventeen years of growth of GDP at the slightly lower annual rate after the effects of the cost increases on GDP growth have been taken into account, from Dixon and Johnson, 1990, this volume.

From the ORANI simulations, a 1% p.a. annual increase in costs to road transport via a tax increase (resulting in a surcharge of 18.4% after the seventeen years from 1988 to 2005) would reduce the base forecast of (GDP) growth by 2.5%, from 3.4400% p.a. to 3.4313% p.a., a cost in the year 2005 of 0.254% of the 1988 GDP; in the base-case 2005 GDP would be 77.71% greater in real terms than that of 1988. The effects in the intervening years would be a lower percentage of each year's GDP.

From Table 3, to attain the Toronto target with the Goldemberg Improvements to fuel efficiency would require fuel prices to rise at between 2.8% and 4.7% p.a., and the improvements to fuel efficiency would, if progressively introduced over the seventeen years, lead to an increase in new car prices of 1.32% p.a. above the base case, so that in 2005 the cost of a new car would be 25% higher than the case without the improvements. Assuming that 7% of the Australian fleet is newly purchased each year, the effect of the rise in new car prices would be to increase costs overall by 0.09% p.a.

Table 4 summarises the effects on the base case GDP growth (of 3.44% p.a.) of the various scenarios and presents the present values of the forgone growth in GDP for the two discount rates of 5% p.a. and 10% p.a.

TABLE 4. Economic costs of abatement scenarios.

	Change in Annual GDP Growth (% p.a.)	Economic Cost: 5% p.a. Discount Rate (1989 $ million)	Economic Cost: 10% p.a. Discount Rate (1989 $ million)
1. Electricity costs rising at 1.5% p.a. (increased inputs)	0.05895	21,031	12,351
2. Electricity costs rising at 0.5% p.a. (increased taxes)	0.00075	268	158
3. Total electricity costs (1. + 2.)	0.0597	21,299	12,509
4. Road transport costs rising at 0.092% p.a. (Goldemberg fuel efficiency improvements)	0.0047	1,667	979
5. Road transport costs rising at 2.8% p.a. (increased taxes)	0.0244	8,707	5,113
6. Road transport, high efficiency (4. + 5.)	0.0291	10,374	6,092
7. Total electricity and road transport, High efficiency (3. + 6.)	0.0888	31,673	18,601
8. Fall in world coal prices of 1% p.a.	0.0159	5,686	3,339

Row 7 presents the cost of joint reductions in emissions from electricity generation and from road transport. The present value at 5% p.a. is $31,673 million (or $18,601 million, at 10% p.a.). Row 8 presents the effect, according to ORANI, of a 1% p.a. fall in world coal prices on the Australian economy. The main effect is a fall in average annual growth in GDP of 0.0159 percentage points p.a. The difference in the present value of the economic growth forgone over the seventeen-year period is calculated as above at $5,686 million at 5% p.a., or $3,339 million at 10% p.a.

It would be incorrect to infer that, because we have given point estimates of prices, quantities, and costs, we are confident in our figures. We have tried to be conservative in our estimates, but the results are sensitive to price elasticities of demand, to growth rates, to time rates of discount, and to the methodology underlying the ORANI model. Nonetheless, we feel confident that the estimates of the present values of the dead-weight losses associated with various scenarios for reducing the CO_2 emission in Australia to the Toronto target of a 20% reduction from 1988 levels are at the low end of projected efficiency costs, and provide a datum for future policy analysis of the cost-effectiveness of ataining the Toronto target.

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