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Short-Run Effects of A Carbon Tax

by

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ABSTRACT

This paper presents estimates of short-run sectoral and economy-wide effects of the introduction of a carbon tax in Australia. The results are derived using an enhanced version of the ORANI multi-sectoral model of the Australian economy.

We simulate the introduction of a carbon tax at a rate of 1991-92 $25 per tonne, designed to achieve the Toronto target of a 20 per cent reduction in carbon dioxide emissions below the 1988 level by 2005. We find that the macroeconomic impact would depend critically on the extent to which price rises flowed through into wage rates. Assuming fixed money wages, real GDP would be decreased by an estimated 0.9 per cent, and employment by 1.2 per cent.

To maintain a given employment level in the face of the carbon tax would require a reduction in the foreign-currency-equivalent wage rate estimated at 2.8 per cent. This would also entail a decrease in the real wage rate (defined with respect to the consumption price deflator) of 2.8 per cent. Government could promote lower wage outcomes by returning the carbon tax revenue to the community through reductions in other taxes.

Enhancements to ORANI used in this simulation include disaggregation of the fossil fuel sector and provision for carbon taxation.

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SHORT-RUN EFFECTS OF A CARBON TAX[1]

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R.A. McDougall

This paper presents estimates of short-run sectoral and economy-wide effects of the introduction of a carbon tax in Australia. The results are derived using an enhanced version of the ORANI model of the Australian economy.

Over recent years there has been much discussion of the enhanced greenhouse effect, actions Australia might take to reduce its contribution to the effect, and the possible costs of such actions. Quantifying the costs is essential to the forming of prudent policy responses. The Commonwealth Government has stated that it will not adopt measures which would have net adverse economic impacts nationally or on Australia's trade competitiveness (see section 1 below).

Several studies have attempted to quantify the costs to Australia of possible greenhouse abatement measures (e.g. Marks, Swan, McLennan, Schodde, Dixon and Johnson 1989, NIEIR and associates 1990, Adams, Dixon, Parmenter and Peter 1991, IC 1991). By and large these studies have concentrated on the ongoing or long-run costs of abatement. While the literature acknowledges that the one-off or short-run costs are also potentially important, relatively little has been done towards quantifying them.

The concern of this paper is with quantifying abatement costs in the short run. Within the short-run analytical framework it also addresses the trade competitiveness effects of abatement measures, identified by the Government as a matter of concern; as argued below (section 6) these effects would be felt chiefly in the short run. It uses as its vehicle of analysis the ORANI multi-sectoral model of the Australian economy, taking advantage of a recent enhancement, the development of a detailed representation of fossil fuel use (Adams and Dixon 1992*b*).

The scenario analysed is the introduction of a carbon tax, set so as to achieve over the long run the Toronto target for carbon dioxide emission abatement in the year 2005.

[1] The research reported in this paper has been undertaken by the Centre of Policy Studies, as part of the MONASH project and the joint ABARE-CoPS project for system-wide analysis of least cost combinations of options to reduce greenhouse gas emissions. The MONASH project has been undertaken with financial assistance from the Commonwealth Government, through the Industry Commission. The greenhouse gas project has been undertaken with financial assistance from the Commonwealth Department of the Arts, Sport, the Environment, and Territories, and the Victorian Office of the Environment. P.B. Dixon made valuable comments on an earlier draft of the paper.

1. Background

A common point of reference for greenhouse policy discussion is the Toronto target. This derives from a conference on 'The Changing Atmosphere and Implications for Global Security' held in Toronto in July 1988. The conference statement called on governments to reduce carbon dioxide emissions to a level of approximately 20 per cent below 1988 levels by the year 2005, as a global goal (Toronto Conference 1988).

In October 1990, the Commonwealth Government adopted an interim planning target of stabilising emissions of greenhouse gases, excluding chlorofluorocarbons and halons, at 1988 levels by the year 2000, and further reducing these emissions by 20 per cent by the year 2005. Targets for chlorofluorocarbons and halons had already been set in the Montreal Protocol on Ozone Depleting Substances. The Government stated that it would not adopt measures which would have net adverse economic impacts nationally or on Australia's trade competitiveness, or in the absence of similar action by major greenhouse gas producing countries (IC 1991 p. B13).

In December 1990 the Government asked the Industry Commission to report on the costs and benefits for Australian industry of an international consensus in line with the Toronto target, but extending its scope from carbon dioxide to all greenhouse gases not already covered by the Montreal Protocol. The Commission reported in November 1991. It found that 'the current state of scientific knowledge does not allow any reasonable estimate to be made of the impacts that would be avoided by a global reduction in greenhouse gas emissions'. It reported simulation results indicating that 'a global cut in carbon dioxide emissions broadly comparable to the Toronto target would lead to a 1.4 per cent decline in Australia's national product', but cautioned that 'Such numbers can have "ball park" significance at best' (IC 1991 pp. 2, 4).

In 1990 also the Government established nine working groups to assist in developing a national strategy for ecologically sustainable development. The Chairs issued in 1992 a greenhouse report drawing together material from the working groups. It recommended 'no regrets' responses, some 'insurance' actions and further research (ESD Working Group Chairs 1992).

Also in 1992 the Government announced a National Greenhouse Response Strategy, involving a number of initiatives aimed at reducing emissions from the energy sector. These included the developing energy standards for household appliances, developing a national Household Energy Rating Scheme, and establishing an Enterprise Energy Audit Program to provide incentives for energy audits (Commonwealth of Australia 1992).

In the course of the Ecologically Sustainable Development process the Chairs commissioned economic modelling by the Centre of Policy Studies (COPS) and the Australian Bureau of Agricultural and Research Economics (ABARE). These used the ORANI general equilibrium model of the Australian economy, and the MENSA linear programming model of the Australian energy sector. A major focus was economic aspects of greenhouse gas abatement (Adams *et al*. 1991, Jones, Naughten, Peng and Watts 1991).

A recommendation from the process was that these modelling activities be continued, and be linked. Work subsequently continued at COPS and ABARE, with funding first from the

Department of the Prime Minister and Cabinet, and later from the Department of the Arts, Sport, the Environment and Territories and the Victorian Office of the Environment. This paper and the enhanced version of ORANI used in it are among the products of this work.

2. Preliminary discussion

The scenario represents the introduction of a carbon tax as an instrument of greenhouse policy. The postulated policy target is the Toronto target, of reducing carbon dioxide emissions in 2005 to the equivalent of 80 per cent of the 1988 level. The tax is introduced at the rate estimated to yield the required degree of abatement in emissions over the long run.

The required degree of abatement is measured by the differerence between the target level of emissions in 2005, and the level that would be generated under business as usual. In principle the abatement applies to all anthropogenic sources of carbon dioxide emissions; in practice we use estimates for the fossil fuel use, which accounts for an estimated 93 per cent of Australian anthropogenic emissions (IC 1991 p. C23).

Australian energy sector emissions of carbon dioxide in 1988 are estimated at 267 million tonnes. Under business as usual they are projected to rise to 378 million tonnes by 2005 (IC 1991 p. 98). The Toronto target is is 80 per cent of the 1988 level, or 214 million tonnes. The target then entails a cut in emissions in 2005 of 164 million tonnes or 43 per cent relative to the base case.

Our scenario then is the introduction of a carbon tax at a rate sufficient to reduce carbon dioxide emissions by 43 per cent over the long run. The tax applies to commodities sold as fuels to domestic consumers. To avoid double taxation, it does not apply to domestic non-fuel use such as refining or distribution. Neither does it apply to exports, though it does apply to fuel used in producing goods for export.

A possible objection to this scenario is that the Government would probably not introduce all at once a carbon tax of the postulated magnitude, but would be more likely to phase it in gradually. This may well be so, though the effects of the tax on consumer prices would for many goods be surprisingly small. For instance, the carbon tax on automotive gasoline would be roughly 6 cents per litre (1991-92 basis). But even if the Government did introduce the tax in several stages, the results presented here would still be relevant.

To a linear approximation, the effects of introducing a carbon tax are proportional to the size of the tax. Over the short run, when relatively little substitution is possible between energy products, the linear approximation is likely to be satisfactory, given the uncertainties inherent in the analysis. If the tax is introduced in several stages, then the effects of each individual stage are proportional to the tax change at that stage, and can be calculated by multiplying the effects of the total tax by the appropriate factor.

If for instance the tax is introduced in two equal stages, then the short-run effects of each stage would be equivalent to one half of the effects of introducing the tax all at once. The results presented here could thus be used to estimate the effects of each individual stage. The cumulative short-run effects of introducing the tax in stages would be equivalent to the short-run effects of introducing the tax all at once; although with phasing there would be no point in time at which all the short-run effects and only the short-run effects were felt.

3. Model

3.1. Framework

We use ORANI in its original comparative-static mode. In this mode, simulation results are reported as deviations from a base case. They do not represent changes over time, but differences with respect to the base case at a given point in time.

We chose the closure of the model to represent a short-run economic environment. Short-run ORANI results are commonly reckoned as representing economic responses over a period of about two years (Cooper, McLaren and Powell 1985).

The model is consistent with the neo-classical dichotomy between the price level on the one-hand and relative prices and real activity on the other. At least one price must be set exogenously; if just one price is set exogenously, it acts as *numeraire* for the model. All other prices move then in line with the numeraire.

3.2. Database

The database used in this application is based on an enhanced ORANI database developed for the greenhouse gas project undertaken jointly by COPS and ABARE. In this database the commodity ‘oil, gas, and brown coal’ has been disaggregated into six new commodities (Adams and Dixon 1992*a*):

— crude oil,

— natural gas,

— liquefied petroleum gas, natural

— brown coal (lignite),

— brown coal (briquettes), and

— oil, gas, and brown coal not elsewhere classified.

The disaggregation is based on the ABS input-output commodity classification (IOCC). It is appropriate to the present application, since it separates commodities which vary greatly in emission intensity, and consequently in exposure to a carbon tax.

With this disaggregation we distinguish seven fossil fuels in the database:

- black coal,

- liquefied petroleum gases, natural,
- natural gas,
- brown coal (briquettes),
- brown coal (lignite),
- petroleum and coal products, and
- gas.

We do not treat crude oil as a fuel, since as shown in the database it is used essentially as an input into the production of petroleum and coal products, or as an export. Note that liquefied petroleum gas (LPG) is included not only in the commodity 'liquefied petroleum gases (natural)' but also in 'petroleum and coal products'. Note also that the commodity 'gas' represents reticulated natural gas and town gas.

To determine the effect of the carbon tax on fuel prices we need to know for each fuel its *emission intensity*, defined as the quantity of carbon dioxide emitted when the fuel is burned divided by the value of the fuel. Knowing the emission intensity and the specific tax rate (measured in dollars per tonne of carbon dioxide) we can calculate the ad valorem tax rate (measured as a percentage of the value of the fuel).

We include emission intensities for each fossil fuel in the database. Table 1 shows these emission intensities and the resultant ad valorem tax rates. Calculations and sources are documented in appendix 2.

Table 1: **Emission intensities and tax rates for fossil fuels, 1986-87**

Commodity	*Emission intensity*	*Tax rate*[a]
	(kt CO_2/$ m)	(%)
Black coal	76	144
Liquefied petroleum gas	9	8
Natural gas	33	63
Brown coal (briquettes)	101	194
Brown coal (lignite)	134	257
Petroleum and coal products	8	15
Gas (reticulated)	9	18

NA Not available
a Percentage of basic value.
Source: COPS estimates.

The *ad valorem* tax rates shown in table 1 are defined with respect to *basic values* of fuel commodities. The basic value is the value at the point of production (or, for imports, the point of entry into Australia), excluding any commodity taxes. It therefore excludes any costs incurred in bringing goods from their point of production (or importation) to the end user. For some goods and end users these costs are substantial; for these goods the *ad valorem* tax rates defined with respect to values at purchasers' prices would be significantly lower than the rates defined with respect to basic values.

In applying the tax we take account of the fact that the same commodity may be used sometimes as a fuel and sometimes in other ways. For instance, natural gas is used mostly as a fuel, but in the petroleum and coal products industry it is used as feedstock. To avoid double counting and mispecifying the scope of the carbon tax, the model should apply it only where the commodity is used as a fuel. To enable the model to do this, we include in the database coefficients indicating the share of use of each commodity in each demand category which is to be counted as fuel use.

For the fuel use shares, our general rule is to treat all use of the seven fossil fuel commodities in the model as fuel use. The exceptions to this rule are in intermediate usage of fossil fuels by the petroleum and coal products and gas industries. For the petroleum and coal products industry, we treat as fuel use half of its usage of its own output, but none of its usage of other fossil fuel commodities. The derivation of this one half share is described in appendix 2. For the gas industry, we treat none of its usage of fossil fuels as fuel use: we assume that it distributes or converts to town gas all its inputs of fossil fuel commodities.

An industry may be exposed to the carbon tax either directly, as a user of fossil fuels, or indirectly, through backward linkages to other fuel using activities. We may measure its direct exposure by its *emission intensity*, defined as the ratio of carbon dioxide emissions to output value. The industry's emission intensity in turn can be expressed as the product of its fossil fuel intensity and an emission coefficient, representing an average ratio of carbon dioxide emissions to energy delivered for the fossil fuels used in the activity:

$$\begin{aligned}&\text{Emission intensity } (\text{kt CO2 / \$m})\\ &= (1/1000) \times \text{Fossil fuel intensity } (\text{TJ / \$m}) \times \text{Emission coefficient } (\text{kt CO2 / PJ}).\end{aligned}$$

The disaggregation of oil, gas and brown coal in the database enables the model to reflect more accurately the variation in emission coefficients across activities. Table 2 shows how variations in fossil fuel intensity and emission coefficients contribute to variations in emission intensities over some of the main carbon dioxide emitting activities. Activities with low emission coefficients include household consumption and transport, while those with high emission coefficients include coal mining, electricity generation, and pulp and paper making.

One implication from table 2 and the data in appendix 1 is that emission coefficients vary much less over activities than over fuels. Emission coefficients for fuels vary over the range from 50 to 95 kilotonnes of carbon dioxide per petajoule (the lowest coefficient is for natural gas, the highest for brown coal). But no activity relies exclusively on a single fuel type. So the emission coefficients in table 2 for the fuel mixes used in different activities vary over a considerably smaller range, 65 to 88 kilotonnes per petajoule.

The data presented in tables 1 and 2 are somewhat out of date, relating as they do to the year 1986-87. This is because the database is based on ABS input-output tables, for which 1986-87 is the most recent available reference year. Since the structure of the economy for the most part changes only slowly over time, the lack of a recent reference year need not detract greatly from the value of model results. Nevertheless a database representing a more recent year is clearly desirable, and is one of the MONASH project's major objectives.

Table 2: **Carbon dioxide emissions and emission intensities for selected activities, 1986-87**

Activity	*CO2 emissions*	*Fossil fuel intensity*	*Emission coefficient*	*Emission intensity*
	(Mt)	*(TJ/$m)*	*(kt/PJ)*	*(kt CO2/$m)*
Household consumption	30.2	3.0	65.2	0.2
Road transport	4.5	6.6	67.7	0.4
Petroleum and coal products	5.3	7.7	67.8	0.5
Rail and other transport	2.3	8.5	67.1	0.6
Air transport	4.4	13.4	67.8	0.9
Pulp, paper, paperboard	1.7	14.5	80.9	1.2
Basic iron and steel	8.3	17.4	75.6	1.3
Other basic chemicals	4.4	19.4	72.4	1.4
Black coal	10.5	21.0	88.3	1.9
Non-ferrous metals	15.9	27.6	76.0	2.1
Cement	2.8	61.5	66.0	4.1
Electricity	104.2	111.1	82.0	9.1

Sources: COPS estimates.

4. Simulation specification

4.1. Shocks

As explained in section 2, the contingency simulated is the introduction of a carbon tax at a rate expected to reduce carbon dioxide emissions by 43 per cent over the long run. The reduction in emissions over the short run would be expected to be much less than 43 per cent; many fuel switching and energy saving measures involve changes in capital equipment, and would be available to firms and households not as short-run options but only in the medium to long run.

The rate of tax needed to reduce carbon dioxide emissions to the target level over the long run depends upon the flexibility of fuel mix and energy use in all economic activities. In its current state of development, the version of ORANI used in this paper allows no flexibility in fuel mix or energy use in production. This is obviously far too restrictive, and prevents us from using the model to estimate the required tax rate. We use instead an estimate obtained in a previous study, 1988 $22 per tonne of carbon dioxide (IC 1991 p. 189), using another purpose-built ORANI version. Work is in train developing the version of ORANI used in this paper to incorporate flexibility in fuel use and energy use.

To use the estimated tax rate of 1988 $22 per tonne with the 1986-87 ORANI database, we deflate it from 1988 to 1986-87 dollars. For the deflator we use the implicit price deflator for expenditure on gross domestic product, which rose 13 per cent over the period. This gives a rate of 1986-87 $19 per tonne. The equivalent 1991-92 rate would be $25 per tonne.

In principle the tax applies to domestic fuel usage, but excludes exports and (in principle) domestic non-fuel use. As described above, we specify in the database the share of usage of each commodity in each usage category in the model which is to be counted as fuel usage.

4.2. Closure

The closure is based on the standard short-run closure of ORANI (Dixon *et al.* 1982 pp. 142-7). The main features of this closure are as follows.

- Each industry's stock of capital is fixed. This is the usual defining feature of the short run.
- The macro components of aggregate absorption are fixed in real terms. These components are household consumption, 'other usage' (mostly government consumption), and investment.

  > By placing these on the exogenous list, we are setting an economic environment in which real aggregate demands are controllable independently of ... other variables ... The underlying assumption is that policy makers have available macro instruments, not explained in ORANI, by which they can influence [household consumption and private investment]. (Dixon *et al.* p. 146)
- The money wage rate is fixed, in the face of any rises in prices resulting from the carbon tax. Several labour market stories are consistent with this treatment. For instance, enterprise bargains may specify wage rates for some considerable period in advance, without providing for indexation against product prices. We discuss this aspect of the economic environment further below.
- The labour market is *slack*; labour is in excess supply, so that employers can get as much labour as they want at the going wage rate.
- The exchange rate is fixed. This might be brought about by the government operating on interest rates and inflationary expectations. As discussed further below, we can also reinterpret the results from the model to be consistent with any change in the exchange rate. In this interpretion the price variables in the model represent not Australian dollar prices, but their foreign currency equivalents.

5. Results

Simulation results for selected macroeconomic variables are reported in table 3. The carbon tax raise output prices, especially for energy-intensive commodities. This results in a loss of competitiveness in trade-exposed industries, both export-oriented and import competing (the export price index rises by an estimated 0.6 per cent). This leads to a contraction in the aggregate export volume, estimated at 6.0 per cent. The deterioration in domestic competitiveness tends to expand the import volume; but changes in the composition of demand (discussed further below) have an opposite and slightly stronger effect, so that overall the import volume contracts slightly (-0.2 per cent). Taking exports and imports together, net exports contract significantly (by the equivalent of 0.9 per cent of GDP).

Table 3: **Estimated short-run macroeconomic effects of imposing a carbon tax of 1986-87 $19 per tonne of carbon dioxide**
(percentage changes)

Real GDP	-0.9
Aggregate export volume	-6.0
Aggregate import volume	-0.2
Employment	-1.2
Consumer price index	1.9
Export price index	0.6
Returns to capital	-1.3

With domestic absorption fixed, the contraction in net exports leads to an equivalent fall in gross domestic product (-0.9 per cent); this in turn entails a fall in employment (-1.2 per cent). At the same time real wages are falling; with consumer prices rising by 1.9 per cent, and money wages unchanged, the real wage falls by 1.9 per cent.

Estimated effects of the carbon tax on sectoral activity are shown in table 4, and results for selected industries in table 5. The sectors most adversely affected are metal products (with a contraction in activity of 6.5 percent), mining (-5.8 per cent), and electricity, gas and water (-3.4 per cent).

The contraction in activity in the metal products sector (-6.5 per cent) occurs mostly in the non-ferrous metals industry (-17.8 per cent). This industry is a heavy user of electricity and gas (which account for 9 per cent of total costs as recorded in the database), and is highly export oriented (exports accounting in the database for 50 per cent of total sales). Faced with higher energy costs, and unable to pass them on to foreign customers, it suffers a severe loss in export sales (-29 per cent). This accounts for most of the reduction in its total sales.

Table 4: **Effects of imposing a carbon tax of 1986-87 $19 per tonne of carbon dioxide, on activity by broad sector** (percentage changes)

Agriculture, forestry etc	-1.3
Mining	-5.8
Food products	-1.3
Textiles, clothing and footwear	-0.6
Wood and paper products	-0.3
Chemicals and petroleum products	-2.1
Non-metallic mineral products	0.2
Metal products	-6.5
Transport equipment	-1.3
Other machinery and equipment	-3.1
Other manufacturing	-1.2
Electricity, gas and water	-3.4
Construction	1.3
Transport and communication	-0.6
Other services	0.2

Table 5: **Effects of imposing a carbon tax of 1986-87 $19 per tonne of carbon dioxide, on activity in selected industries** (percentage changes)

Non-ferrous metal ores	-6.1
Black coal	-11.2
Crude oil	-0.5
Liquefied petroleum gas	-1.2
Natural gas	-4.4
Brown coal (briquettes)	-20.8
Brown coal (lignite)	-5.4
Petroleum and coal products	-2.8
Non-ferrous metals	-17.8
Electricity	-4.8
Gas (reticulated)	-4.9

The contraction in mining sector activity occurs mainly in non-ferrous metal ores (-6.1 per cent) and black coal (-11.2 per cent). The briquettes industry also contracts sharply (-21 per cent) but is too small to have any considerable effect on overall mining activity.

The black coal industry contracts for similar reasons to the non-ferrous metals industry discussed above. The industry is a moderately heavy user of energy (6 per cent of total costs), largely in the form of coal consumed on site and electricity. At the same time it is highly export oriented (exports account in the data reference year for almost 80 per cent of total sales). Finally, its export sales are treated in the model as particularly price-sensitive, even compared to other major export commodities (this reflects the fact that Australia holds a smaller share of the world coal market than for instance the wool market, so that foreign coal buyers can switch to other suppliers more easily than wool buyers). The outcome in the simulation is a severe decline in export sales (-13 per cent).

The contraction in output non-ferrous metal ores results mainly from lower usage by the non-ferrous metals industry (discussed above). The very severe contraction in briquettes output results partly from the severe effect of the carbon tax on briquette prices (the *ad valorem* tax rate is almost 200 per cent), and partly also from substitution away from briquettes in household consumption. Household consumption of briquettes falls by an estimated 43 per cent.

The contrast between the severe contraction in briquettes output and the more moderate contraction in other fossil fuels draws attention to an asymmetry in the current ORANI theoretical structure. This provides for substitution between commodities in household consumption, but not in intermediate usage. The result is that demand for consumption goods is typically more price-sensitive than demand for intermediate goods.

This asymmetry can be defended on the grounds that in many cases there are severe technical limitations on substitution between commodities in intermediate usage. The generally low price sensitivity of demand for intermediate goods is arguably a desirable feature of the model. On the other hand, there are cases where some substitution between intermediate inputs is possible, and applications where these substitution possibilities are critical to the analysis. One of the objectives of the MONASH energy project is to generalise the theoretical structure to allow greater flexibility in intermediate usage.

For the electricity, gas and water sector the contraction in activity occurs mainly in electricity (-4.8 per cent) and gas (-4.9 per cent). For both electricity and gas, the contraction in sales volume is largely accounted for by substitution away from electricity and gas in the household sector and lower usage by their largest industrial customer, the non-ferrous metals industry.

While most sectors contract when the carbon tax is imposed, there are some that expand. Construction activity expands by 1.3 per cent, non-metallic mineral products by 0.2 per cent, and ‘other’ services by 0.2.

The expansion in construction activity results from a change in the composition of investment. The sectors most adversely affected by the carbon tax are those in which investment is weighted relatively heavily towards plant and equipment. So the composition of investment shifts away from plant and equipment to construction. But by assumption in the closure, aggregate real investment is fixed. So construction activity expands, and so too does usage of non-metallic mineral products, which consist largely of building materials.

In passing, we note that this change in the composition of investment helps to explain the simulated contraction in the volume of imports. Imports have a large share of the plant and equipment market, but only a small share in construction. The shift in investment away from equipment towards construction reduces the overall propensity to import.

The ‘other’ services sector benefits from being oriented largely towards consumption goods, less energy-intensive than other consumer goods and services, and subject to relatively little import competition. Being less energy-intensive than other consumer goods and services, it benefits from the tax-induced change in the composition of household consumption. With aggregate real consumption fixed by assumption, the compositional change translates into a strengthening in household demand for ‘other services’. With import competition weak, most of this strengthening in demand flows to domestic output.

The uneven impact of the carbon tax on different industries leads to uneven effects on employment in different occupations. As table 6 shows, the greatest reductions are in blue-collar occupations: employment of plant and machine operators and drivers falls by 2.9 per cent, and of labourers and tradespersons by 1.5 per cent. These occupations rely heavily for employment on the manufacturing, mining, and utilities sectors that the carbon tax affects most severely. On the other hand, the least affected occupations are those of less skilled white-collar workers, employed largely in the service sector. Employment of salespersons and personal services workers falls by only 0.5 per cent, and employment of clerks by 0.7 per cent.

Table 6: **Effects of imposing a carbon tax of 1986-87 $19 per tonne of carbon dioxide, on rates of employment by occupation** (percentage changes)

Managers and administrators	-1.0
Professionals	-0.9
Para-professionals	-0.8
Tradespersons	-1.5
Clerks	-0.7
Salespersons and personal services workers	-0.5
Plant and machine operators and drivers	-2.9
Labourers and related workers	-1.5

6. Discussion

6.1. Assessing the simulation results

What do the results presented above indicate about the short-run adjustment task that a carbon tax would impose?

The simulated short-run fall in gross domestic product, at 0.9 per cent, would clearly represent a serious cost to the community. On the other hand, to the community at large, it would be something less than catastrophic: it would be equivalent for instance to only a fraction of the cost of the recent recession, though not a very small fraction.

While the cost of the recession cannot be determined precisely, the loss of production in 1991-92, compared to that which would have been achieved on a more stable growth path, may be reckoned conservatively at about 5 per cent of GDP. This is the difference between actual output and that which would have been achieved with steady growth of 3 per cent per year, starting from average output over the period 1984-85 to 1986-87 (thus factoring out not only the recent recession but also the boom which immediately preceded it). The estimated short-run output loss from the carbon tax is about one sixth of this.

While the cost to the community as a whole might be bearable, the cost to the some individual sectors and regions would of course be much more severe. The simulation results show severe contraction in output in just three industries: black coal (-11.2 per cent), briquettes (-21 per cent) and non-ferrous metals (-18 per cent), and one of these industries (briquettes) is very small. Over the medium run however severe contraction would be expected in other industries. In particular the brown coal (lignite) industry might be largely eliminated (c.f. IC 1991, Jones, Naughten *et al*. 1991). The estimated reduction in aggregate employment (-1.2 per cent) would entail severe hardship for some households.

Since domestic absorption is held fixed in the short-run simulation, the decrease in aggregate demand arises entirely from a deterioration in trade competitiveness. Trade competitiveness deterioriates because after-tax energy prices rise in Australian dollar terms, while Australian dollar wage rates and the exchange rate are assumed to remain fixed. Under these assumptions, the maintenance of trade competitiveness and the maintenance of aggregate output and employment are essentially equivalent tasks.

Over the long run we would expect the real exchange rate to adjust so as to offset any initial deterioration in trade competitiveness. A permanent deterioration in trade competitiveness would involve a permanent shift away from purchasing power parity in the exchange rate, and a permanent shift away from full employment in the labour market. Since we have no basis for predicting permanent shifts away from equilibrium in exchange rates and wage rates, we regard the loss of trade competitiveness from a carbon tax as a short- to medium-run phenomenon.

By some measures the estimated short-run cost is surprisingly small. It may for instance be compared with an estimate in an earlier study, of a long-run fall of 2.1 per cent (IC 1991). This estimate relates to the same rate of carbon tax as used in this study. Taking both estimates at face value, the implication would be that the effects of a carbon tax would be more severe over the long run than over the short run.

In assessing such a conclusion, we need to review carefully the assumptions embodied in the short-run closure. One major assumption is that the government, through some unspecified instrument, maintains consumption and investment constant in real terms, in the face of the declines in national income and national competitiveness. More specifically, referring to the results as simulated, the government maintains constant real consumption in the face of a fall of 0.9 per cent in real GDP, and constant real investment in the face of a fall in real returns to capital of 2.3 per cent (using the investment price index as the deflator). Thus government is assumed to engage and succeed in a considerable demand management task.

A major factor in the relatively small short-run fall in GDP is the government's assumed success in insulating aggregate absorption from the carbon tax over the short-run. This insulation however cannot be maintained indefinitely. In the study previously referred to (IC 1991), real consumption is estimated to fall by 1.6 per cent over the long run, and real investment by 3.4 per cent. These falls account on the expenditure side for most of the long-run reduction in GDP.

The assumption that government could and would maintain aggregate consumption and investment at predetermined levels over the short run is clearly unrealistic. Investment demand in particular is hard to predict and hard to control. And in the recent recession, government has not engaged in demand management on a scale that would have stabilised consumption or investment. From this experience it might seem realistic to allow for significant short-run contractions in consumption and investment. The magnitude of these contractions however cannot be estimated within the model version used here.

Another reason why the estimated long-run effects are more severe than the short-run effects relates to the effects of the carbon tax on the industrial structure. The tax induces much more reallocation of resources over the long run (when capital can move freely between industries) than over the short run (when capital is fixed). The direction of reallocation is away from lower cost processes with higher emission levels towards higher cost processes with lower emission levels. For any given level of aggregate resource use, the reallocation towards higher cost processes leads to a reduction in aggregate output.

The other critical assumption underlying the short-run results is the assumption of constant money wage rates. With the recent emergence of a mixed system of arbitration and enterprise bargaining, the appropriate treatment of wage determination is currently far from clear. We consider here some simple approaches.

If wages were set largely by centralised bargaining, and this was conducted frequently or made provision for indexation, then the appropriate modelling treatment might be to assume fixed real wages. With fixed real wages, the effects of the carbon tax on competitiveness, output, and employment would be much more severe than in the fixed money wage case reported above. Supplementary simulations with fixed real wages show a fall in GDP of 2.3 per cent, almost three times as great as with fixed money wages.

Against this, it might be urged that government would be likely to take action to lessen the contractionary effect of the carbon tax, for instance by seeking a wage-tax bargain. With the revenue from the carbon tax, the Commonwealth Government would be well placed to offer a reduction in income tax. On a 1991-92 basis, at the initial level of emissions, the carbon tax revenue would amount to around $8 billion.

This however leads to the question, how much government could afford to offer in an income tax cut. The income tax cut would be funded by a carbon tax which had the objective of reducing carbon dioxide emissions, in effect reducing its own tax base. Over the long run, if the tax did succeed in its object of reducing emissions by 43 per cent, the tax base would be only 57 per cent of its base-case level.

We may consider two cases. In one the government offers to reduce income tax by the value of the carbon tax revenue, calculated on the initial level of emissions. It offers to reduce all income tax rates in equal proportion, so that the percentage reduction in tax on wage income is equal to the percentage reduction in total income tax. In return, wage rates are discounted, relative to the rates that would otherwise have been set, so as to reduce gross wage income at initial employment levels by an amount equivalent to the reduction in tax on wage income. The other case is similar, except that here the amount of the overall income tax reduction is equal to the value of the carbon tax revenue calculated on the initial level of emissions less 43 per cent.

In the first case, wage rates are discounted by 2.3 per cent relative to the level at which they would otherwise be set. In the second case, they are discounted by 1.3 per cent. Now since with zero wage indexation consumer prices would rise by an estimated 1.9 per cent, zero wage indexation with no discounting would be equivalent to full wage indexation with a 1.9 per cent discount. So full wage indexation with the larger wage-tax bargain would deliver lower wages than zero wage indexation, but with the smaller wage-tax bargain would deliver higher wages.

With decentralised wage bargaining the situation becomes still less clear. Relevant considerations would include the length of time that wage agreements were specified to hold for, whether provision was made for indexation against prices within this time, and (if such provision was made) the choice of price index. Arguments could be advanced for a wide range of modelling treatments, including zero, partial, or full wage indexation.

Of the two issues, the absorption response and the wage response, the latter appears more fundamental. With sufficient wage flexibility the international competitiveness effects of the carbon tax could be partly or fully offset; if they were offset, then the effects of the tax on aggregate domestic absorption would also be likely to be neutralised. The wage response therefore appears as the critical factor in determining the short-run macroeconomic impact.

6.2. A different approach

From the above, it is clear that the short-run macroeconomic effects of a carbon tax depend critically on the wage response to the tax, and that the wage response is in the present changing labour market regime quite uncertain. This suggests that it would be useful to develop some measure of the short-run stabilisation task presented by the tax that would be independent of assumptions made about the performance of the labour market.

While there is debate over the degree to which wage bargaining is and should be decentralised, there seems to be little support for the proposition that government should abandon wages policy. However wage outcomes are determined, they are still considered a proper object of government and public concern. Accepting that there is a role for wages policy, there remains the question what its task should be. It seems clear that a large part of the task would be to stabilise employment, counteracting at least partially any external shocks that would tend to increase unemployment.

This suggests a different approach to assessing the macroeconomic impact of environmental policy changes, in terms of the additional burdens they place on wages policy. They add to the wages policy task if they lower the wage rate consistent with a given rate of unemployment, and reduce the task if they raise the wage rate consistent with a given unemployment rate. We may therefore use the change in the fixed-employment wage rate as an indicator of the macroeconomic impact of the environmental policy.

The question arises, whether to use the real wage rate or the money wage rate in assessing the macroeconomic impact. When wage rates display both nominal and real stickiness both measures have some apparent usefulness. We argue however that in the economic environment assumed in these simulations the money wage rate measure requires reinterpretation.

The money wage rate consistent with a given level of employment depends on the exchange rate. A currency depreciation increases the fixed-employment wage rate, an appreciation lowers it. As discussed above however ORANI cannot determine the exchange rate. We have therefore assumed arbitrarily in setting up the simulations that the exchange rate is fixed. Since this assumption is arbitrary, the money wage rate indicator also appears arbitrary.

We can however use the theoretical properties of the model to reinterpret the money wage rate measure in such a way that it ceases to be arbitrary. With a fixed rate of employment, the exchange rate acts as a *numeraire* in the model. All domestic prices vary in proportion with the exchange rate, in such a way that the equivalent foreign-currency prices are invariant with respect to the exchange rate. We therefore reinterpret the money wage rate indicator as the change in the foreign-currency-equivalent wage rate consistent with zero change in the employment level.

To estimate these policy impact indicators we have conducted a supplementary simulation, in which wage rates vary so as to hold the level of employment fixed over the short run in the face of the carbon tax shock. In this simulation, with employment constant, the money wage rate falls by 2.8 per cent, consumer prices remain almost unchanged, and the real (pre-tax) wage rate falls by 2.8 per cent. This reduction in wage rates would help to preserve external competitiveness, so that the fall in exports would be reduced from 6.0 per cent to 1.6 per cent, and the fall in GDP from 0.9 to 0.1 per cent. Together with compositional changes, this would suffice to maintain employment at a constant level.

We therefore describe the macroeconomic impact of the carbon tax, by saying that it would lower by 2.8 per cent the real wage rate consistent with the initial level of employment. Alternatively, it would lower by 2.8 per cent the foreign-currency-equivalent wage rate consistent with the initial employment level.

In seeking to maintain employment in the face of the tax shock, the government would have several options open to it. It could seek to lower wage rates by 2.8 per cent, take other policy actions which would raise the fixed-employment wage rate by 2.8 per cent, or adopt a combination of both approaches.

Under the previous more centralised wage fixing regime the government might have sought a reduction in wage rates through a wage-tax bargain, based on the return of the carbon tax revenue through income tax cuts. Even under the new less centralised regime some limited role might remain for such a policy. As discussed above, a wage-tax bargain by itself, even on the most favourable assumptions, would achieve a wage reduction of only 2.3 per cent. This would not reduce wages sufficiently to maintain the initial employment level, though it would go a long way towards it.

It is not clear *prima facie* why the cost reductions from the wage-tax bargain fail fully to offset the competitiveness effects of the carbon tax itself. Detailed analysis of this feature of the results would be needed before definite policy conclusions could be drawn from it.

Another approach would be to return the carbon tax revenue through cuts not in income tax but in indirect taxes. This would have the effect of raising the fixed-employment wage rate. Whether this approach would succeed in maintaining employment would depend in part on the characteristics of the sectors receiving tax relief. If these sectors were relatively insensitive to taxation, this approach would not succeed in maintaining employment; if they were highly sensitive, it might even bring about a net increase in employment. Insofar as the indirect tax cuts were permanent, they would need to be assessed not only for their short-run macroeconomic implications but also for their longer-run implications for equity and allocative efficiency.

7. Conclusions

The paper has examined short-run sectoral and macroeconomic effects of a carbon tax designed to meet the Toronto target for carbon dioxide emissions over the long run. Among industries, the sectoral effects are most severe on fossil fuel extraction and on non-ferrous metal ores extraction and processing. The fossil fuel industries are hit directly by the tax, while the non-ferrrous metals industries are vulnerable because of their energy intensity and their export orientation. Among occupations, blue-collar occupations are hardest hit.

The macro fallout from the tax would pose the government and nation a significant stabilisation problem. Effective wage restraint, demand management, or both would be needed to avoid significant adverse effects on trade competitiveness and employment. Any estimate of the short-run macroeonomic effects depends sensitively on the degree of success projected to be achieved in these policy areas. If nominal wage rates, aggregate real consumption, and aggregate real investment were held fixed, the tax would reduce GDP over the short run by an estimated 0.9 per cent.

One measure of the size of the stabilisation policy task is the degree of wage restraint needed to maintain trade competitiveness and employment in the face of the tax shock. Estimates from the model indicate that employment could be stabilised with a reduction of 2.8 per cent in wage rates, adjusted for exchange rate changes. This could be brought about by cuts in Australian dollar wages (with the exchange rate constant), currency depreciation (with Australian dollar wage rates constant), or a combination of the two. A wage-tax bargain, based on the government's returning through income tax cuts the revenue raised through the carbon tax, could go part of the way to achieving the necessary wage reduction, but would not eliminate the need for real after-tax wage cuts. Another approach would be to use the carbon tax to fund cuts in other indirect taxes.

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Appendix 1: Changes to the ORANI theoretical structure

The theoretical structure for the model was a modified version of GIANT, an enhanced version of ORANI or precursor of MONASH. Modifications were made to adapt GIANT to short-run comparative static analysis, and to facilitate the modelling of a carbon tax.

GIANT is a medium-run forecasting model, so for the present application it was modified for short-run comparative static analysis. This involved the reintroduction of the ORANI short-run investment theory (Dixon *et al.* 1982 pp. 118-22), the deletion of the ORANI-F medium-run investment theory (Parmenter 1988 pp. 2-5), and various minor modifications.

To facilitate the modelling of a carbon tax, the GIANT treatment of commodity taxation was replaced by a new treatment. The GIANT treatment would have required tax shocks to be calculated separately for each different use of each affected commodity. The new treatment allows users to specify a single carbon tax rate, defined in dollars per tonne of carbon dioxide.

We assume that the only source of change in commodity tax rates is the introduction of a carbon tax, at a specific rate defined in dollars per tonne of carbon dioxide. We convert this specific rate to an *ad valorem* rate for each fuel using its *emission intensity*, defined as the ratio of the mass of carbon dioxide it emits when burned, to its price. We measure the emission intensity in kilotonnes of carbon dioxide per millions of dollars of fuel. Given the emission intensity and the change in the specific tax rate (from zero to $19 per tonne of carbon dioxide), we can calculate the percentage point change in the *ad valorem* tax rate for each fuel according to the formula

$$\begin{aligned}&\text{Change in ad valorem tax rate } (\%)\\ &= \text{Change in specific tax rate } (\$/\text{t CO2}) \times \text{ Emission intensity } (\text{kt CO2}/\$\text{ m})/10\end{aligned} \qquad (1)$$

(the factor of 1/10 is needed to reconcile the units in which the various terms in the equation are measured).

In ORANI, the commodity tax regime is specified in terms of the *power* of the tax, or the ratio of the tax-inclusive to the tax-exclusive price of each commodity. The absolute change in the power of the tax is equal to the absolute change in the *ad valorem* tax rate. From this we can derive a formula for the percentage change in the power of the tax,

$$\begin{aligned}&\text{Percentage change in power of tax}\\ &= \frac{\text{Tax - exclusive value}}{\text{Tax - inclusive value}} \times \text{Change in ad valorem tax rate } (\%).\end{aligned} \qquad (2)$$

This formula requires elaboration to take account of the fact that the same commodity may be used sometimes as a fuel and sometimes in other ways. For instance, natural gas is used mostly as a fuel, but in the petroleum and coal products industry it is used as feedstock. To avoid double counting and mispecifying the scope of the carbon tax, the model should apply it only where the commodity is used as a fuel.

To enable the model to do this we define a set of coefficients indicating for each commodity and domestic demand category whether the use of that commodity in that category is to be treated as fuel use, non-fuel use or a mixture of the two. The coefficients represent the share of fuel use in total use of each commodity in each domestic demand category. Using these coefficients, we modify equation (2), to read

$$\text{Percentage change in power of tax}$$
$$= \frac{\text{Use as a fuel}}{\text{Use for all purposes}} \times \frac{\text{Tax - exclusive value}}{\text{Tax - inclusive value}} \times \text{Change in ad valorem tax rate} \;\; (\%). \tag{3}$$

We add equations (1) and (3) to the equation system (see attachment to appendix 3).

The changes to the theoretical structure entailed changes to the database. These included changes to the updatable and invariant parameters files, and the addition of a new emissions data file. The settings of the emissions data are described in appendix 2.

Appendix 2: Calculation of emission data for 1986-87

We describe in this appendix the calculation of the emission intensities, and of the fuel use share for intra-industry usage of petroleum and coal products.

We calculate emission intensities in two passes. In the first pass we cover six of the seven fossil fuels in the model — black coal, liquefied petroleum gas, natural gas, brown coal (briquettes), brown coal (lignite), and petroleum and coal products. In the second pass we cover the remaining commodity, gas (i.e. reticulated natural gas and town gas).

In the first pass we calculate the emission intensity of each commodity as the quotient of the quantity of emitted carbon dioxide (measured in kilotonnes) and the value of the commodity (measured in millions of dollars). The emission and value are for total domestic usage; they include domestic usage of imports, but exclude exports. The commodity is assessed at its basic value, i.e. ex-mine or ex-works value (for domestic production) or landed duty-paid value (for imports).

We obtain the value data for this calculation from ABS input-output statistics (ABS 1990*a*, *b*), Adams and Dixon (1992*b*). We calculate the quantity of emitted carbon dioxide as the product of domestic energy use (measured in petajoule) and an emission coefficient (measured in kilotonne of carbon dioxide per petajoule). We obtain energy use data from ABARE statistics (Jones, Bush *et al*. 1991), and emission coefficients from unpublished ABARE estimates (Thorpe, S. 1993 pers. comm. 28 April).

With energy use we need to adapt the ABARE statistics for liquefied petroleum gas (LPG) to the ORANI commodity classification. The ORANI classification, following the ABS IOCC, distinguishes between naturally occurring LPG (classified as ‘liquefied petroleum gas’) and other LPG (classified under ‘petroleum and coal products’). The ABARE statistics do not make this distinction.

The ABARE statistics show domestic consumption of LPG in 1986-87 as 57.3 PJ. We assign 46.5 PJ to naturally occurring LPG, and 10.8 PJ to other LPG. The assignment is based on calculations using ABARE energy statistics and ABS input-output statistics.

With emission coefficients, we apply the ABARE emission estimate for brown coal to both briquettes and lignite. For petroleum and coal products we average ABARE estimates for several products (automotive gasoline, automotive diesel oil, etc.). We calculate the average using energy use weights from the ABARE energy use statistics. Note that the data used in the calculation cover only part of the commodity classification ‘petroleum and coal products’; we treat this part as representative of the whole.

Table A1 shows the calculation of the average emission coefficient for petroleum and coal products. Table A2 shows the calculation of emissions for all fuel commodities covered in the first pass (i.e. all except ‘gas’). Table A3 combines the emissions estimates with value data to calculate emission intensities.

Table A1: **Carbon dioxide emissions from petroleum and coal products, 1986-87**

	Energy consumption	*Emission coefficient*	*Emissions*
	(PJ)	(kt/PJ)	(Mt)
LPG	10.8	59.4	0.6
Auto gasoline-leaded	497.8	66.0	32.9
Auto gasoline-unleaded	47.8	66.0	3.2
Aviation gasoline	3.7	67.8	0.3
Aviation turbine fuel	93.5	67.8	6.3
ADO	335.5	69.7	23.4
Fuel oil	98.6	73.3	7.2

ADO Automotive diesel oil.

LPG Liquefied petroleum gas.

Sources: Jones, Bush *et al*. (1991), Thorpe (pers. comm.).

Table A2: **Carbon dioxide emissions, 1986-87**

Fuel	*Domestic usage*	*Emission coefficient*	*Emissions*
	(PJ)	(kt CO2/PJ)	(Mt)
Black coal	1236.9	90.0	111.3
Liquefied petroleum gas	46.5	59.4	2.8
Natural gas	588.4	50.5	29.7
Brown coal (briquettes)	17.1	95.0	1.6
Brown coal (lignite)	405.0	95.0	38.5
Petroleum, coal products	1286.1	67.9	87.3

Sources: Jones, Bush *et al*. (1991), Thorpe (pers. comm.).

Table A3: **Carbon dioxide emission intensities, 1986-87**

Fuel	*Domestic usage*	*Emissions*	*Emission intensity*
	($ m)	(Mt)	(kt/$ m)
Black coal	1474.4	111.3	75.5
Liquefied petroleum gas	300.5	2.8	9.2
Natural gas	889.6	29.7	33.4
Brown coal (briquettes)	16.1	1.6	100.9
Brown coal (lignite)	286.3	38.5	134.4
Petroleum, coal products	11166.1	87.3	7.8

Sources: ABS (1990*a*,*b*), unpublished ABS estimates, COPS estimates.

For the ‘gas’ industry (reticulated natural gas and town gas) we calculate an emission intensity for output based on emission intensities for inputs. We assume that the amount of carbon dioxide released in burning the industry’s output is equal to the amount that would have released in burning the industry’s fossil fuel inputs. The calculation is shown in table A4.

Table A4: **Carbon dioxide balance for the gas industry**

	Emission intensity	*Value*	*Carbon dioxide potential*
	(kt / $m)	($m)	(Mt)
Inputs			
Black coal	75.5	0.8	0.1
Liquefied petroleum gas	9.2	29.2	0.3
Natural gas	33.4	421.4	14.1
Brown coal (briquettes)	100.9	0.0	0.0
Brown coal (lignite)	134.4	0.0	0.0
Petroleum products	7.8	8.0	0.1
Other inputs	0.0	1116.1	0.0
Total/average	9.2	1575.5	14.5
Output			
Gas	9.2	1575.5	14.5

For the fuel use shares, our general rule is to treat all use of the seven fossil fuel commodities in the model as fuel use. The exceptions are in intermediate usage of fossil fuels by the petroleum and coal products and gas industries. For the petroleum and coal products industry, we treat as fuel use half of its usage of its own output, but none of its usage of other fossil fuel commodities. For the gas industry, we treat none of its usage of fossil fuels as fuel use: we assume that it distributes or converts all its fuel inputs.

The one-half share for intra-industry usage of petroleum and coal products was calculated as follows. The energy content of the gross output of petroleum and coal products in 1986-87 was 1233.3 PJ, while energy used in conversion was 83.1 PJ (Jones, Bush *et al*. 1992). Gross output of petroleum and coal products was valued at \$10 410.0m (ABS 1990*b*). So the average price of energy carried in petroleum and coal products was (\$10 410.0m ÷ 1233.3 PJ), or \$8.441m per PJ.

We assume that all energy used in conversion was carried in petroleum and coal products, and that the price of energy carried in petroleum and coal products and used in the petroleum and coal products industry was equal to the average price of energy carried in petroleum and coal products. Then the value of petroleum and coal products used as fuel by the petroleum and coal products industry was (\$8.441m per PJ × 83.1 PJ), or \$701m. But total intra-industry usage of petroleum and coal products was valued at \$1372.8m (ABS 1990*a*). So the share of fuel use in total intra-industry usage of petroleum and coal products was (\$701m ÷ \$1372m), or approximately 50 per cent.

Appendix 3: Computer implementation

The theoretical structure for the model was a modified version of GIANT, an enhanced version of ORANI or precursor of MONASH. Modifications were made to adapt GIANT to short-run comparative static analysis, and to facilitate the modelling of a carbon tax, as described in appendix 1.

The modified equation system is given in a TABLO source code file GEV2.TAB. The changes to the code between GEV2.TAB and the original GIANT model are shown in an attachment. User input into TABLO was provided in a DCL command file TBGEV2.COM. The executable file was named GEV2.EXE.

The database was modified from GIANT. The original data files for GIANT were stored as FID87.HAR (the updatable data file), FIDPAR87.HAR (the invariant parameters file), and EXTRA.HAR (a file containing forecasting data not used by the revised theoretical structure). The updatable data file and invariant parameters file were modified to support the reintroduction of the ORANI short-run investment theory. A new file containing emission-related data was created to support the modelling of the carbon tax. The EXTRA.HAR file was discarded.

The main change to the updatable data file was the reintroduction of the G investment parameters (ratios of current gross investment to the next-period capital stock in each industry) from the ORANI short-run investment theory. The main change to the invariant parameters file was the reintroduction of the ORANI beta investment parameters (elasticities of the expected next-period rate of return with respect to the next-period capital stock in each industry).

The emissions data file contains two sets of arrays. The first set comprises just one array, showing for each commodity an emission intensity, measured in kilotonnes of carbon dioxide per million dollars (for settings of the emission intensities see appendix 2). The second set comprises one array for each kind of domestic demand category in the model (intermediate usage, investment usage, household consumption, and 'other' demands). These arrays contain the shares of fuel use in total use for each commodity and domestic demand category.

The emission intensities were calculated in spreadsheets CEPPC.XLS (average emission coefficient for petroleum and coal products), IE.XLS, (emission intensities for fossil fuels other than 'gas'), and IEG.XLS (emission intensity for gas).

The database changes were made using MODHAR. User inputs were provided in stored input files MHID.STI (for the updatable data file), MHPM.STI (for the invariant parameters file), and MHGEEM.STI (for the emissions data file). Values for investment parameters were read from the files P025.TXT (for the beta investment parameter) and P026.TXT (for the G investment parameter). The new data files were named GEV2ID87.HAR (the updatable data file), GEV2PM87.HAR (the invariant parameters file), and GEV2EM87.HAR (the emissions data file).

User input to run the TABLO-generated program, to create the equations file, define the closure, and test for price homogeneity, was supplied in a GEMPACK command file GEV2.CMF. The equations file was named GEV2.EQ4. The closure was stored in an environment file GEV2.EN4.

User input into SAGEM for the carbon tax simulation was supplied in a GEMPACK command file TCGEV2.CMF. Besides specifying the shock to the carbon tax rate variable *ratetaxcarb*, this file specified closure changes and shocks relating to investment. These changes were made to ensure that gross investment in all industries remained positive. The industries requiring constraint were:

— high rainfall zone,

— northern beef,

— natural gas,

— brown coal (briquettes),

— brown coal (lignite),

— non-ferrous metals, and

— agricultural machinery.

The solution file was named TCGEV2.SL4, and the print file TCGEV2.PI5.

To determine the effects of the carbon tax with full wage indexation, a supplementary simulation was performed with an alternative invariant parameters file. This file was made using MODHAR, with user input from file MHGE2IPM.STI. It was called GE2IPM87.HAR. Using this file, a new equations file was created, by the program GEV2.EXE, with user input from the command file GE2I.CMF. It was given the name GE2I87.HAR. The carbon tax simulation was rerun with this equations file, with user input from the command file TCGE2I.CMF. The solution file was called TCGE2I.SL4, and the print file TCGE2I.PI5.

To determine the degree of wage discipline needed to maintain full employment in the face of the carbon tax shock, a supplementary simulation was conducted, with aggregate employment (*l*) fixed and the general wage shift variable (*fwage*) endogenous. The files relating to this simulation include the command file TWGEV2.CMF, the solution file TWGEV2.SL4, and the print file TWGEV2.PI5.

Calculations relating to carbon tax revenue were performed in a spreadsheet CTREV.XLS.

Attachment.   Changes to the TABLO source code

Deleted code

```
VARIABLE
del_time # Shocked to one for 'dynamic' simulations, else 0          #;
taxrate1 # Uniform % Change in Powers of Taxes on Intermediate Usage #;
taxrate2 # Uniform % Change in Powers of Taxes on Capital Creation   #;
taxrate3 # Uniform % Change in Powers of Taxes on Household Usage    #;
taxrate5 # Uniform % Change in Powers of Taxes on "Other" Usage      #;
(ALL,j,IND) f_accum(j)      # shifter on capital accumulation equation      #;
(ALL,i,COM) powtax(i)       # Power of the General Sales Tax                #;

EQUATION MONEY_WAGES # 22.6 flexible setting of money wages #
(ALL,j,IND) (ALL,k,OCC)
p1laboi(j,k)= xi3 + fwage + fwagei(j) + fwageo(k) + fwageoi(j,k);
! we assume that AH1OI(o,j),the parameter to index wages to cpi is unity !

EQUATION POW_INT_TAX # power of tax on sales to intermediate #
(ALL,i,COM)(ALL,s,SOURCE)(ALL,j,IND)
!(TAX1(i,s,j)+BAS1(i,s,j)+TINY)*(powtax1(i,s,j)-powtax(i)-taxrate1) =
 TAX1(i,s,j)*(xi3 - p0(i,s));      !
powtax1(i,s,j) = powtax(i) + taxrate1;

EQUATION POW_CAP_TAX # power of tax on sales to investment #
(ALL,i,COM)(ALL,s,SOURCE)(ALL,j,IND)
!(TAX2(i,s,j)+BAS2(i,s,j)+TINY)*(powtax2(i,s,j)-powtax(i)-taxrate2) =
 TAX2(i,s,j)*(xi3 - p0(i,s));    !
powtax2(i,s,j) = powtax(i) + taxrate2;

EQUATION POW_HOUS_TAX # power of tax on sales to households #
(ALL,i,COM)(ALL,s,SOURCE)
!(TAX3(i,s)+BAS3(i,s)+TINY)*(powtax3(i,s)-powtax(i)-taxrate3) =
 TAX3(i,s)*(xi3 - p0(i,s));   !
powtax3(i,s) = powtax(i) + taxrate3;

! powtax4(i) is normally endogenous for some commodities !

EQUATION POW_OTH_TAX # power of tax on sales to other #
(ALL,i,COM)(ALL,s,SOURCE)
!(TAX5(i,s)+BAS5(i,s)+TINY)*(powtax5(i,s)-powtax(i)-taxrate5) =
 TAX5(i,s)*(xi3 - p0(i,s));    !
powtax5(i,s) = powtax(i) + taxrate5;

!****************************************************************************!
FILE EXTRA               # timely data #;

COEFFICIENT (INTEGER) NYEARS # Number of years #;
READ NYEARS FROM FILE extra HEADER "NYRS";  ! This is a parameter !

SET YEARS MAXIMUM SIZE 20 SIZE NYEARS;

COEFFICIENT (all,uu,YEARS) UUVAL(uu) # UUVAL(uu) = uu for uu = 1 to NYEARS #;
READ UUVAL FROM FILE extra HEADER "UVAL";

COEFFICIENT (ALL,j,IND) WW(j) # R(0)/R(T)#;
READ WW FROM FILE EXTRA HEADER "WWWW"; ! set to one prior to dynamic sim !
UPDATE (CHANGE)  (ALL,j,IND)
 WW(j) =  WW(j)*[curcap(j)-y(j)]/100;
```

```
COEFFICIENT (ALL,j,IND) ZZ(j) # K(0)/K(T)#;
READ ZZ FROM FILE EXTRA HEADER "ZZZZ"; ! set to one prior to dynamic sim !
UPDATE (CHANGE)  (ALL,j,IND)
 ZZ(j) =  -ZZ(j)*[curcap(j)]/100;

!*****************************************************************************!

COEFFICIENT (ALL,j,IND) R_0(j) # Y(0)/K(0)#;
FORMULA (ALL,j,IND) R_0(j) = WW(j)*R_T(j); ! this should turn out a constant !

COEFFICIENT (ALL,j,IND) DEP_T(j) # DEP to the power of T #;
FORMULA (ALL,j,IND) DEP_T(j) = DEP(j)^NYEARS;

COEFFICIENT (ALL,j,IND) N_term(j) # useful constant #;
FORMULA (ALL,j,IND) N_term(j) =
    SUM(uu,YEARS, DEP(j)^{NYEARS -UUVAL(uu)} );  ! note uu takes values 1 to T !

COEFFICIENT (ALL,j,IND) M_term(j) # useful constant #;
FORMULA (ALL,j,IND) M_term(j) =
    SUM(uu,YEARS,([UUVAL(uu)-1]/NYEARS)*DEP(j)^{NYEARS -UUVAL(uu)} );

COEFFICIENT (ALL,j,IND) K0_SHOCK(j) # k0 shock coefficient  #;
FORMULA (ALL,j,IND) K0_SHOCK(j) = [DEP_T(j) + R_0(j)*N_term(j) - 1.0]
          *ZZ(j)*100.0 ;

COEFFICIENT (ALL,j,IND) YCOEFF(j);
FORMULA (ALL,j,IND) YCOEFF(j) = M_term(j) * R_T(j);

COEFFICIENT (ALL,j,IND) CHECK_1(j) ;
FORMULA (ALL,j,IND) CHECK_1(j) = - K0_shock(j) / ycoeff(j);
COEFFICIENT (ALL,j,IND) CHECK_2(j) ;
FORMULA (ALL,j,IND) CHECK_2(j) = 1 / ycoeff(j);

EQUATION YK_ACCUM # investment/capital accumulation #
(ALL,j,IND)
 curcap(j) = K0_SHOCK(j)*del_time + YCOEFF(j)*y(j) + f_accum(j);

WRITE N_term         TO FILE DISFILE;
WRITE M_term         TO FILE DISFILE;
WRITE DEP_T          TO FILE DISFILE;
WRITE K0_SHOCK       TO FILE DISFILE;
WRITE YCOEFF        TO FILE DISFILE;
WRITE CHECK_1        TO FILE DISFILE;
WRITE CHECK_2        TO FILE DISFILE;
```

Inserted code

```
SET EXOIND # Industries with exogenous investment #
(I5, I6, I10, I21, I88 - I90, I98, I101, I102, I108 - I113, I116, I117);
SUBSET EXOIND is subset of IND;

!P****************************************************************************!
!                 CARBON TAX VARIABLES                                        !
!*****************************************************************************!

VARIABLE
(CHANGE) ratetaxcarb # carbon tax rate, specific #;
(CHANGE) (ALL,i,COM)(ALL,s,SOURCE) radvalcarb(i,s)
 # carbon tax rate, ad valorem #;

!P****************************************************************************!
```

```
!                  CARBON TAX COEFFICIENTS                                     !
!******************************************************************************!

COEFFICIENT (ALL,i,COM)(ALL,s,SOURCE) EMISS_INTENS(i,s)
 # emission intensity, kt/$m #;
READ EMISS_INTENS FROM FILE EMISS HEADER "E001";
UPDATE (CHANGE) (ALL,i,COM)(ALL,s,SOURCE: EMISS_INTENS(i,s) NE 0)
 EMISS_INTENS(i,s) = [-p0(i,s)/100.0];

COEFFICIENT (ALL,i,COM)(ALL,s,SOURCE)(ALL,j,IND) SHRF1(i,s,j)
 # share of fuel usage in total intermediate usage of i from s by j #;
READ SHRF1 FROM FILE EMISS HEADER "E002";

COEFFICIENT (ALL,i,COM)(ALL,s,SOURCE)(ALL,j,IND) SHRF2(i,s,j)
 # share of fuel usage in total investment usage of i from s by j #;
READ SHRF2 FROM FILE EMISS HEADER "E003";

COEFFICIENT (ALL,i,COM)(ALL,s,SOURCE) SHRF3(i,s)
 # share of fuel usage in total household usage of i from s #;
READ SHRF3 FROM FILE EMISS HEADER "E004";

COEFFICIENT (ALL,i,COM)(ALL,s,SOURCE) SHRF5(i,s)
 # share of fuel usage in total "other" usage of i from s #;
READ SHRF5 FROM FILE EMISS HEADER "E005";

!P*****************************************************************************!
!                  CARBON TAX EQUATIONS                                        !
!******************************************************************************!

EQUATION RATE_ADVAL_CARBTAX # ad valorem equivalent rate of carbon tax #
(ALL,i,COM)(ALL,s,SOURCE)
radvalcarb(i,s) = (EMISS_INTENS(i,s)/10.0)*ratetaxcarb;

!    Factor of (1.0/10.0) results from
     -  factor of (1.0/1000.0) needed to adjust difference in units between
        ratetaxcarb and EMISS_INTENS, and
     -  factor of 100.0 needed to convert radvalcarb from fractional to
        percentage point change.                                               !

EQUATION POW_INT_TAX # power of tax on sales to intermediate #
(ALL,i,COM)(ALL,s,SOURCE)(ALL,j,IND)
   (BAS1(i,s,j) + TAX1(i,s,j) + TINY)*powtax1(i,s,j)
 = SHRF1(i,s,j)*BAS1(i,s,j)*radvalcarb(i,s);

EQUATION POW_CAP_TAX # power of tax on sales to investment #
(ALL,i,COM)(ALL,s,SOURCE)(ALL,j,IND)
   (BAS2(i,s,j) + TAX2(i,s,j) + TINY)*powtax2(i,s,j)
 = SHRF2(i,s,j)*BAS2(i,s,j)*radvalcarb(i,s);

EQUATION POW_HOUS_TAX # power of tax on sales to households #
(ALL,i,COM)(ALL,s,SOURCE)
  (BAS3(i,s) + TAX3(i,s) + TINY)*powtax3(i,s)
= SHRF3(i,s)*BAS3(i,s)*radvalcarb(i,s);

! powtax4(i) is normally endogenous for some commodities !

EQUATION POW_OTH_TAX # power of tax on sales to other #
(ALL,i,COM)(ALL,s,SOURCE)
  (BAS5(i,s) + TAX5(i,s) + TINY)*powtax5(i,s)
= SHRF5(i,s)*BAS5(i,s)*radvalcarb(i,s);

!P*****************************************************************************!
!                  INVESTMENT VARIABLES                                        !
```

```
!******************************************************************************!

VARIABLE (CHANGE)                                            omega
     # economy-wide expected rate of return on fixed capital #;

VARIABLE (ALL,j,IND) f2(j) !Shift in investment in industry j!;

VARIABLE (all,j,ind) futcap(j) !Future fixed capital stock in industry j!;

!P*****************************************************************************!
!                 INVESTMENT COEFFICIENTS                                       !
!******************************************************************************!

COEFFICIENT (ALL, i, IND) BETA(i);
READ BETA FROM FILE PARAMS HEADER "P025";

COEFFICIENT (ALL, i, IND) GCOEFF(i);
READ GCOEFF FROM FILE FID HEADER "P026";
UPDATE (CHANGE) (ALL,j,IND) GCOEFF(j) = (y(j) - futcap(j))*GCOEFF(j)/100.0;

!P*****************************************************************************!
!                 INVESTMENT EQUATIONS                                          !
!******************************************************************************!

EQUATION INVEST_INDUST_END
!19.8 Economy wide expected rate of return on fixed capital!
(ALL,j,ENDIND)
omega = -BETA(j)*[futcap(j) - curcap(j)] + r0(j);

EQUATION FUT_CAP_STK
!19.9 Future fixed capital stock in industry j!
(ALL, j, IND)
futcap(j) = [1.0 - GCOEFF(j)] * curcap(j) + GCOEFF(j) * (y(j)-
f2(j));

EQUATION INVEST_INDUST_EXO
!19.11 Creation of fixed capital in industry j!
(ALL, j, EXOIND)
y(j) = prinvr + f2(j);

!P*****************************************************************************!
!                 WAGE INDEXATION COEFFICIENT                                   !
!******************************************************************************!

COEFFICIENT AH1
 # wage indexation parameter #;
READ AH1 FROM FILE PARAMS HEADER "PI01";

!P*****************************************************************************!
!                 WAGE INDEXATION EQUATION                                      !
!******************************************************************************!

EQUATION MONEY_WAGES # 22.6 flexible setting of money wages #
(ALL,j,IND) (ALL,k,OCC)
p1laboi(j,k)= AH1*xi3 + fwage + fwagei(j) + fwageo(k) + fwageoi(j,k);
```