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ABSTRACT

The Australian government has announced to price carbon at an initial price of $23 per tonne. Despite detailed modelling undertaken by the Commonwealth Treasury, there is widespread speculation about the possible economic impact of a carbon tax in Australia. In this paper we build a computable general equilibrium (CGE) model incorporating many new features to deal with the issue of emissions and model the impact of carbon taxes. The analysis undertaken by simulating the impact of a carbon tax of $23 a tonne reveals some interesting outcomes. For example, in the short run, Australia's real GDP may decline by 0.68 percent, consumer prices may rise by 0.75 percent, and the price of electricity may increase by about 26 percent as a result of the tax. Nevertheless it allows Australia to make a substantial cut in its CO2 emissions. The simulation results imply an emission reduction of about 12 percent in its first year of operation. The tax burden is unequally distributed among different household groups with low-income households carrying a relatively higher burden.

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1. Introduction

The Australian government has announced that it will price carbon by introducing a carbon tax from July 1st 2012 with a view to transforming the policy to a market-based emissions trading scheme in three to five years time from its introduction (Gillard, 2010). The tax will begin as a fixed price of $23 per tonne of CO2-e (CO2 equivalent).The government also has its plan to reduce Australia's emissions to 5 per cent below 2000 levels by 2020 as the voluntary target in the absence of a coherent international agreement on the level of carbon emission reduction. Any policy for reducing carbon pollution, whether it is a carbon tax or tradable emission permits, will increase the price of energy. The tax is likely to have an economy-wide impact affecting Australia's GDP, industrial structure and trade. The policy to cut emissions is regressive and the tax burden will be unequally distributed among different household groups with low-income households carrying a relatively higher burden.

There are many different ways of encouraging the transmission from carbon-intensive energy to alternative low-emission energy uses. Australia has used the policy of subsidising low-emission energies and new technologies over the last five years. The programs included investing directly to improve wind and solar energy, in using biomass waste from sugar mills, in geothermal energy from hot dry rocks, and to extract more hydropower through cloud-seeding (Humphreys, 2007). This approach known as 'picking winners' has its own drawbacks due to high capital content in technologies involved and the bias in political decision making. It is argued that market based approaches are superior to political processes in picking winners in an attempt to reduce greenhouse gases.

The decision by the Australian government to adopt direct market based approaches to reducing emissions by a carbon tax will have an impact on the relative prices of goods and services. When the emitters begin passing on the costs of the tax into the prices of their products, low-carbon or carbon-free goods and services become cheaper than high carbon intensive ones. This change in relative prices will lead industries to substitute away from carbon-intensive inputs to low-carbon inputs and primary factors; and consumers (households) to reduce the use of carbon-intensive goods and services in their consumption bundle. These behavioural changes will have feedback effects on the economy's resource allocation, industry structure and product-mix, economic growth, and income distribution. Such economy-wide effects cannot be discerned in a partial equilibrium modelling approach and hence they require more complex general equilibrium models which use input-output data as the benchmark of the economy. This paper analyses the impact of a carbon tax in Australia using a computable general equilibrium (CGE) model developed for that purpose.

The paper is organised as follows. Section 2 presents previous literature concerning the effects of environmental policies that relate to climate change and carbon tax using CGE modelling. Section 3 describes the model structure and the database and Section 4 discusses the simulation results with special reference to the macro-economy, industrial sectors and households. Concluding remarks are in Section 5.

2. Literature Review

There is a large body of literature on carbon dioxide emissions and climate change, so it is not necessary, even if possible, to review all of them. Instead, we will confine our review to CGE modelling on carbon tax policies.

Hamilton and Cameron (1994) used a CGE model, a static cost-push I/O framework and a micro-simulation model to estimate the effect of a hypothetical carbon tax in Canada. The CGE model by Beausejour et al. (1992) of the Canadian Department of Finance is used to determine the carbon tax rate in order to achieve the Rio target in Canada – stabilising emissions at the 1990 level by the year 2000. Based on this carbon tax, the cost-push I/O framework is used to estimate the price changes on consumer goods and the Statistics Canada's micro-simulation model is employed to gauge the distributional effects on individuals, families and households. The CGE modelling showed that a tax of CA$102 (or US$84) per tonne of carbon is needed to achieve the Rio target. They also compared the effect of a carbon tax, a fossil fuel tax and emission standards, and concluded that the fossil fuel tax is the most distortionary in terms of real income changes, gross output changes and the amount of tax revenues; the emission standards policy yields the greatest decline in real GDP, and the carbon tax produces the smallest declines in income, GDP and gross output.

Using a time recursive dynamic CGE model, Zhang (1998) analysed the macroeconomic and sectoral effects of carbon taxes to cut China's carbon emissions in 2010 by 20 per cent and 30 per cent. The Chinese I-O table 1991 was aggregated into 10 sectors, which included 4 energy sectors – coal, oil, natural gas and electricity. In the production function, these four energy inputs form the energy composite through a Cobb-Douglas function. The labour and capital inputs form a capital-labour composite in the same fashion. A CES function is used to combine the capital-labour composite and the energy composite to form a factor composite. The gross output is the Leontief combination of the factor composite and intermediate inputs. Besides the two basic scenarios (the emission cut by 20 per cent and 30 per cent in 2010, with carbon tax revenue retained by the government), four indirect tax-offset scenarios were also simulated, namely, reducing indirect taxes by 5 per cent or 10 per cent in each basic scenario. The simulation results suggest that, under the two basic scenarios, China's GNP drops by 1.5 per cent and 2.8 per cent, and its welfare reduces by 1.1 per cent and 1.8 per cent, compared with the baseline case. If the carbon tax revenues were used to offset reductions in indirect taxes, the negative effects of carbon taxes on GNP and welfare would be reduced. At the sectoral level, the changes in gross output vary significantly – the coal sector is affected most severely. It is also concluded that, aggregate gross output tends to decrease at an increasing rate as the carbon emission target becomes more stringent, and that a greater cut in carbon emission will require a higher carbon tax, which implies higher prices of fossil fuels.

Labandeira et al. (2004) were interested in the double dividend of environmental taxation – introducing a revenue-neutral environmental tax to reduce distortions caused by other tax levies thereby achieving an efficiency dividend as well as an environmental one. Using a conventional energy-focused CGE model as well as an econometric model of household demand for energy goods, they simulated a hypothetical tax reform in Spain with an introduction of a tax on carbon emissions and a simultaneous reduction in social security contributions. Their simulation shows that a carbon tax of 12.3 Euros per tonne of carbon dioxide would reduce carbon emissions by 7.7 per cent and reduce the marginal rate of social security contributions by 11.7 per cent. It is found that real GDP decreases by 0.7 per cent, real capital income falls by 0.7 per cent but real labour income increases by 0.2 per cent and social welfare improved substantially – a 256 million Euro increase in equivalent variation in real terms.

Wissema and Dellink (2007) used a CGE model to quantify the impact of implementing energy taxation to reduce carbon emissions in Ireland. They built a static model of a small open economy with 7 energy commodities and 19 other commodities. The production structure is a tree of nested production functions. The energy and primary inputs demand is described by multiple levels of two-input CES functions, with elasticity of substitution values adopted from GTAP-E (Rutherford and Paltsev, 2000) and Kemfert (1998). The simulation results suggest that the 25.8 per cent reduction target for energy related carbon emissions in Ireland (compared to 1998 levels) can be achieved with a carbon energy tax of 10 to 15 Euros per tonne of carbon dioxide, but the results are sensitive not only to the ability of fuel switching but also to the possibilities for producers to substitute away from energy. They also compared the effect of a carbon tax and an equivalent uniform energy tax. It is concluded that, while the latter has a stronger negative impact on less polluting energy sectors, the former generates a greater cuts in carbon emissions, stimulates the use of renewable energy and reduces the use of peat and coal.

Based on the simulation results from a CGE model for South Africa, Devrajan et al. (2011) investigated the interaction between tax policies to reduce carbon emissions and distortions in the economy. The tax options include a carbon tax, a sales tax on energy commodities, and a sales tax on pollution-intensive commodities. The level of each tax is adjusted to meet the emissions target – 15 per cent cut in emissions in South Africa, so the effects of three tax policies are comparable. The distortions considered are mainly those in the labour market, e.g. labour market segmentation or wage differentials for the same type of labour across sectors. Through imposing or removing labour market distortions, the paper compared the performance of each tax policy. The paper also investigated the influence of elasticity of substitution among energy inputs and between energy and capital by comparing the results from three cases: the reference case where relatively higher elasticity values are used, the rigid case where the elasticity values are halved and the Leontief case (there is no substitution effect). The main findings of the paper are: a carbon tax gives the least marginal cost of abatement. The welfare losses from a tax on carbon are small regardless of the elasticities of substitution in production but it is regressive – it will hurt low-income households more. If a carbon tax is not feasible, a sales tax on energy inputs may be the next-best policy.

Given the distortions in labour market, it has a higher overall welfare cost than a carbon tax, but it is less regressive. The sales tax on pollution-intensive outputs is of least efficient – it costs around 10 times as much as the carbon tax in both reference and rigid cases.

In Australia, CGE modelling on carbon emissions and climate change has been undertaken by the Centre of Policy Studies at Monash University, ABARE and the Federal Treasury. As early as in 1993, McDougall at the Centre of Policy Studies simulated the effect of a carbon tax using an enhanced ORANI model incorporating a detailed representation of the Australian energy sector. McDougall (1993a) considered the short-run effects of a carbon tax of $25 per tonne of carbon dioxide which was designed to achieve the Toronto target of a 20 percent reduction in carbon dioxide emissions below the 1988 level by 2005. Following Adams and Dixon (1992), he included seven fossil fuels in the model, namely, black coal, brown coal (lignite), brown coal (briquettes), liquefied petroleum gas, natural gas, petroleum and coal products, and gas. The database is an enhanced ORANI database including 1986-1987 I-O tables by the ABS and energy use and emission data from ABARE. The model is very rigid in that it did not allow flexibility in fuel mix or energy use in production. A very restrictive short-run closure is employed, in which many variables such as the capital stock, money wage rate, exchange rate, and aggregate domestic absorption in real terms (e.g. household consumption, government spending and investment) are assumed fixed (exogenous). The results show that the carbon tax raised output prices, especially for energy-intensive commodities, which results in a loss of competitiveness in trade-exposed industries. GDP fell by 0.9 per cent and employment fell by 1.2 per cent and the real wage rose by 1.9 per cent. Some sectors are badly affected by the carbon tax, with metal production contracting by 6.5 per cent, mining by 5.8 per cent, and electricity, gas and water by 3.4 per cent. To reduce the negative effect of the carbon tax and maintain the employment level unchanged, a lower wage policy is suggested to the government.

McDougall (1993b) used an ORANI-E model to compare the effects of a carbon tax, an energy tax and fuel tax. The database is similar to that for McDougall (1993a), but electricity was disaggregated into six types according to the electricity generation technology used. The model structure had changed substantially to allow the substitution between energy inputs, between capital and composite energy, and among electricity generation technologies. The rates of three taxes –tax on carbon emissions, tax on fossil fuel and tax on petroleum products are chosen so that the revenue collected from each tax are equivalent to 0.5 percent of base case GDP1. Based on the simulation results, it is concluded that, while a carbon tax would be the theoretically ideal instrument for carbon dioxide abatement, an energy tax applying to all fossil fuels would also be reasonably effective. However, a tax on petroleum products is much less effective in cutting greenhouse gases and considerably more costly than either an energy or carbon tax.

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[1] McDougall though this setting would assist comparison of three policies, but with this setting, both the environment effect and economic effect will be different for each tax policy, so it is hard to compare their efficiency (the cost of carbon abatement).

Based on the Monash Multi-Regional Forecasting (MMRF) model, The Centre of Policy Studies developed a MMRF-Green model to address the carbon emissions issue in Australia. Although MMRF-Green is mainly employed in analysing carbon emissions trading (e.g. Allen consulting group, 2000; Adams, 2007), it is used in the Treasury modelling on carbon taxes, so we briefly discuss it here. MMRF-Green is a dynamic, single country, multi-regional model. There are 52 industry sectors, 56 commodities, and eight States (or 57 sub-States). Each State has a single representative household and a regional government. There is also a federal government. Not to change the CGE core substantially, the substitution effect between energy inputs, between electricity generations, and between transports are realized through the different size of various input saving technological changes for each commodity. This is a clever alternative expression of substitution effect, but it is only workable in a dynamic model and in the long run. In a static simulation when technology is assumed unchanged, all these substitution effects will disappear. There are five emission activities. Four of them cover emissions from combustion of black coal, brown coal, natural gas and petroleum products and the other one covers the emissions from fugitive and non-combustion agricultural sources. The emission data were obtained from the National Greenhouse Gas Inventory (NGGI) summary report by the Australian federal government.

The global trade and environment model (GTEM) developed by ABARE was also used in the treasury modelling. GTEM is a dynamic multi-country model, derived from the MEGABARE model and the static Global Trade Analysis Project (GTAP) model. The GTEM uses different production functions for electricity, and iron and steel industries. For these two sectors, the output is produced from an intermediate input bundle and a technology bundle using a Leontief function. The intermediate input bundle is a Leontief combination of different kinds of goods, each of which is a CES combination of domestic good and imported good and the latter in turn is a CES combination of imports from different regions. The technology bundle is formed by different kinds of technology using a CRESH (constant ratio of elasticities of substitution, homothetic) function and each technology uses different technology inputs in fixed proportion (Leontief function). The CRESH function is similar to CES function but it allows different elasticities of substitution between pairs of inputs. For other industries, the producer output is a Leontief combination of intermediate input bundle and the energy factor bundle. The former is a three-layer CES combination of different goods while the latter is a CES combination of the primary factor bundle and energy bundle. The primary factor bundle includes capital, labour, land and natural resources and the energy bundle includes coal, gas, petroleum products and electricity. Both bundles are formed by CES functions. The data in GTEM are mainly from the GTAP database, but data on carbon emissions from fossil fuel combustion are sourced from the International Energy Agency (IEA) and data on non-combustion emissions is compiled from the United Nations Framework Convention on Climate Change's (UNFCCC) national inventory figures for individual countries, or estimated by ABARE.

Ahammad et al. (2004) used the GTEM to estimate the effect of a possible Japanese carbon tax and the implications for the Australian energy sector. Three scenarios are considered in the paper: a tax of ¥3400 (or US$31) per tonne of carbon emission, a tax of ¥45000 (or US$410) per tonne of carbon emission, and a domestic emissions trading scheme by which Japan can meet its Kyoto Protocol commitment. The US$31 carbon tax has a small negative impact on both carbon emissions and economic growth while the US$410 carbon tax is projected to reduce Japan's emissions closer to its Kyoto Protocol target but at a substantial cost to the Japanese economy. In the three policy scenarios, Japan's energy consumption is projected to fall below the reference case level, which adversely affects the competitiveness of Japan's domestic production and reduces the real income of Japanese households. Coal is the most severely affected because it has the highest carbon content. Since Japan is a major importer of Australian coal and liquefied natural gas, Australian exports to Japan are projected to fall, but Australia's exports of coal and other energy goods to alternative destinations would rise, partially offsetting the fall in exports to Japan. This latter result arises because increased cost pressures in Japan favour Japan's competitors, now able to obtain a competitive advantage and expand their global share.

In an effort to introducing a carbon tax in Australia, the Treasury conducted a large-scale carbon price modelling. The Treasury modelling is very ambitious and complex. It consists of a number of models. The GTEM is employed to provide the international economic and emissions context for modelling of the Australian economy. The MMRF is used to project the national, regional and sectoral impact of carbon taxes. With the world carbon price paths being set, the model for the assessment of greenhouse-gas-induced climate change (MAGICC) is used to estimate the greenhouse gas atmospheric concentration levels. The ROAM model by ROAM Consulting and the SKM MMA model by the Sinclair Knight Merz group are used to provide detailed bottom-up information of the Australian electricity generation sector. The Energy sector model (ESM) by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) is used to model the road transport sector. The price revenue incidence simulation model and distribution model (PRISMOD.DIST) are used to examine the distributional implication of carbon pricing for households. The modelling framework and results are included in the Treasury report: Strong growth, low pollution – modelling a carbon price (The Treasury, 2011). Overall, the Treasury modelling results with two starting carbon prices in 2012-13 (A$20 and A$30) are very positive: the economy continues to grow strongly and carbon emissions are reduced substantially. It is projected that, without a carbon tax, Australian GNI per person by 2050 is around 60 per cent higher and emissions are 74 per cent higher than today; with a carbon price, the GNI per person is at least 56 per cent higher and the emissions fall by 80 per cent. In the core policy scenario (starting carbon price in 2012-13 at A$20), around 1.6 million jobs are projected to be created to 2020 and a further 4.4 million to 2050; average weekly household expenditure will be higher by around $9.90 in 2012-13, of which electricity accounts for around $3.30 and gas around $1.50. However, the Treasury modelling may have limitations. One is that, since so many models are used, the accuracy of results is subject to the degree of integration among the models and the way they are integrated.

While the GTEM results provide an international setting for the MMRF, the feedback effects of an Australian carbon tax on the world economy is absent in the modelling. In the integration of MMRF with SKM MMA and ROAM, the iteration process provides a good way to achieve consistent results on the supply of, and demand for, electricity generation and road transport, but the price setting is crucial in the integration and it should be endogenously determined by a CGE model (e.g. through MMRF here). In the report, there is no clear description of price setting in the iteration process, but reading between the lines gives us the impression that the electricity prices are determined by the partial equilibrium models SKM MMA and ROAM2. Another limitation is that, there are numerous assumptions used in the simulation, the change of key assumptions may alter the simulation results substantially. While the dynamic nature of MMRF demands numerous assumptions about the growth trend of the future economy, a micro model (e.g. ESM, SKM MMA and ROAM) needs very specific assumptions. As acknowledged in the Treasury report (The Treasury, 2011), a large number of assumptions are made about global carbon prices, productivity and technological changes, energy efficiency and options, and household taste changes. Although various sources are used, the assumptions based on the projection into the future 10 to 38 years can only be speculative. Consequently, they are subject to large revisions in the future and so are the modelling results.

3. Model Structure and Data

Different from the Treasury's approach, the goal of this paper is quite modest and much more focused: what is the short-run effect of a carbon tax policy if it is adopted by the Australian government? So a static rather than a dynamic model is developed. CGE modelling involves a number of assumptions, the specification of supply and demand functions, the use of disaggregated data and behavioural-parameter values, and simulation shocks. This section considers each in turn.

3.1 Model Structure

Because the purpose of this study is to assess the effect of a carbon tax policy, instead of forecasting the performance of the whole economy overtime under the tax, the model developed for this study is a static CGE model, based on ORANI-G (Horridge, 2000). The comparative static nature of ORANI-G helps to single out the effect of carbon tax policies while keeping other factors unchanged. The model employs standard neoclassical economic assumptions: a perfectly competitive economy with constant returns to scale, cost minimisation for industries and utility maximisation for households, and continuous market clearance. In addition, zero profit conditions are assumed for all industries because of perfect competition in the economy.

The Australian economy is represented by 35 sectors which produce 35 goods and services, one representative investor, ten household groups, one government and nine occupation groups. The final demand includes household, investment, government and exports. With the exception of the production function, we adopted the functions in the

[2] In the Treasury report (2011, p 148), the description about 'Fuel prices' in the left panel of table A4 says: 'Electricity price (from SKM MMA and ROAM)'.

multi-households version of ORANI-G. The structure of production function is shown in Figure 1.

Figure 1 The structure of production function

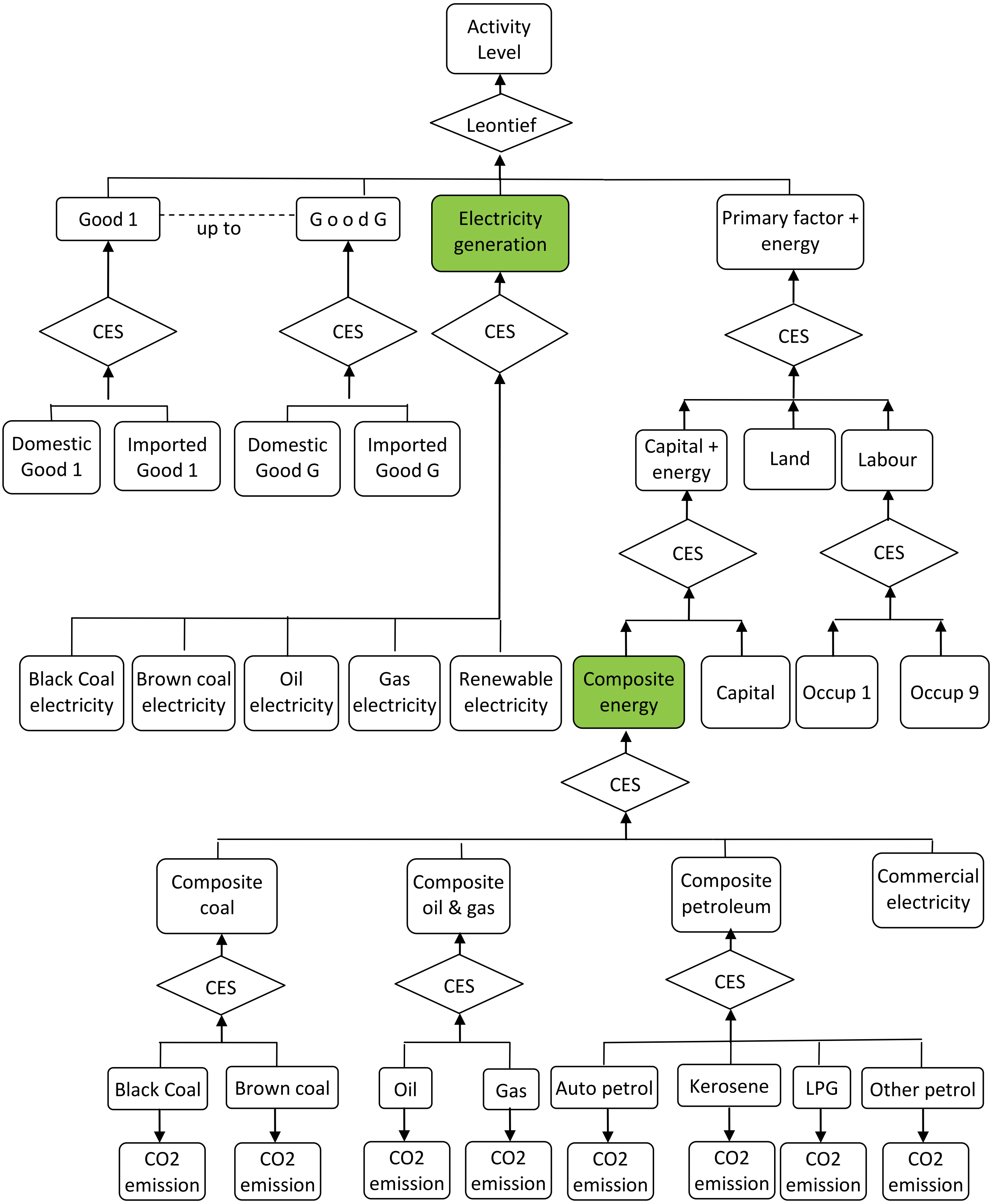

Activity Level
Leontief
Good 1
up to
G o o d G
Electricity generation
Primary factor + energy
CES
CES
CES
CES
Domestic Good 1
Imported Good 1
Domestic Good G
Imported Good G
Capital + energy
Land
Labour
CES
CES
Black Coal electricity
Brown coal electricity
Oil electricity
Gas electricity
Renewable electricity
Composite energy
Capital
Occup 1
Occup 9
CES
Composite coal
Composite oil & gas
Composite petroleum
Commercial electricity
CES
CES
CES
Black Coal
Brown coal
Oil
Gas
Auto petrol
Kerosene
LPG
Other petrol
CO2 emission
CO2 emission
CO2 emission
CO2 emission
CO2 emission
CO2 emission
CO2 emission
CO2 emission

Figure 1 only describes the input demands in production because the product output mix of an industry is determined by a CET function, which is the same as in standard ORANI. Overall, the production function is a five-layer nested Leontief-CES function. As in ORANI model, the top level is a Leontief function describing the demand for intermediate inputs and composite primary factors and the rest is various CES functions at lower levels. However, we have two alterations on demand for electricity generation and energy inputs (the shaded area in Figure 1).

We classify the electricity generation in the economy into five types according to the energy sources used, namely electricity generated from black coal, brown coal, oil, gas and renewable resources. Once generated, the electricity commodity is homogeneous, so there must be a large substitution effect among five types of electricity generation. So we use a CES function to form a composite electricity generation, instead of putting each type of electricity generation in the top level of Leontief function as Adams et al. (2000) did. In this approach, we allow the electricity generation to shift from high carbon-emission generators (e.g. brown coal electricity) to low carbon-emission generators (e.g. gas and renewable electricity).

The other change is the treatment of energy inputs. We argue that the energy efficiency is positively related to the investment on energy-saving devices, e.g. well-insulated housing uses less energy for air-conditioning. So we assume that there are limited substitution effects between energy goods and capital and that the size of substitution effect depends on the cost and the availability of energy-saving technology, which is reflected in the value of the substitution elasticity. A similar treatment of energy inputs has been used by many researchers such as Burniaux et al. (1992), Zhang (1998), Ahammad and Mi (2005), and Devarajan et al. (2009).

We further assume that there are substitution effects among different kinds of energy inputs and the size of effect depends on the similarity among them. There is considerable substitution between brown and black coal, between oil and gas, and between auto petrol, kerosene, LPG and other petroleum. So the demands for these energy inputs are described by the CES functions at the bottom level. At one level above, the composite coal, oil & gas, petroleum, and commercial electricity form composite energy through another CES function.

The way we treat electricity may need more explanation. We only include commercial electricity in the group of energy goods because it is the only electricity type commonly used by each sector. In the construction of database, electricity generation is only used by the electricity sectors and it is sold to the commercial electricity sector (or electricity distributor) who adds some margin and distributional cost and sells to other sectors and final demands. Thus, electricity generation is better to be viewed as having normal composite intermediate inputs (described by a Leontief function) for the electricity sectors, but commercial electricity is treated as an energy input in the other sectors.

Carbon emissions in the model are treated as proportional to the energy inputs used and/or to the level of activity. Based on the carbon emissions accounting published by the Department of Climate Change and Energy Efficiency, we treat carbon emissions in three different ways. First, the stationary fuel combustion emissions are tied with inputs (the amount of fuel used). Based on the emissions data, the input emission intensity – the amount of emissions per dollar of inputs (fuels) – is calculated as a coefficient, and then total emissions are calculated by multiplying the amount of input used by the emission intensity. Second, the industry activity emissions are tied with the output of the industry. The output emission intensity coefficient is also pre-calculated from the emission matrix and it is multiplied by the industry output to obtain the activity emissions by the industry. Third, the activity emissions by household sector are tied with the total consumption of the household sector. The total consumption emissions are obtained by the amount of household consumption times the consumption emission intensity coefficient pre-calculated from the emission matrix. All three types of emission intensity are assumed fixed in the model to reflect unchanged technology and household preferences.

Some researchers (e.g. Centre of Policy Studies, 2008) argue that emission intensity may change with different carbon price levels and consequently an equation is designed to show the negative relationship between the change in emission intensity and that in carbon price. We did not adopt this approach for two reasons. For activity emissions, this reasoning sounds reasonable for a cost-minimizing firm. However, the sources of activity emission are quite complex and the level of activity emissions is hard for the government to detect, so the firm may not respond well to a carbon price. For fuel combustion emissions, it is true that firms will use more of low emission inputs in the face of a carbon tax so the emissions should decrease, but the emission intensity could not decrease because of the slow progress of technology in this area[3]. We further argue that it is not necessary to change emission intensity in our model. One reason is that the substitution effects between high and low emission fuels have already been embedded in the CES function for energy inputs, so it is not necessary to duplicate these substitution effects by changing emission intensity. The other is that the firms' shifting between different energy inputs comes at a cost. For example, using lower emission energy inputs, for example, black coal, may incur additional transportation cost compared with using brown coal nearby. The equipment for coal electricity generation may need substantial alteration so that it can be used as gas electricity generation. This cost has already been taken care of in the elasticity values for the CES function between composite energy and capital.

The functions for final demands are similar to those in the ORANI model (Dixon et al., 1982). For example, the investment demand is a nested Leontief-CES function, the household demand function is a nested LES-CES function. Export demand is dependent on the price of domestic goods, and government demand follows household consumption. However, unlike the assumption of exogenous household either total or supernumerary consumption in ORANI-G, we assume that total consumption is proportional to total income for each household group.

[3] In an earlier working paper of the Centre of Policy Studies, (Adams, et al., 2000) stated, " so far as we know, no advance of this type is likely to be widely adopted with the next 20 years."

The main data used for the modelling include input-output data, carbon emission data, and various behaviour parameters. We briefly discuss each in turn.

The input-output data used in this study are from Australian Input-output Tables 2004-2005, published by ABS. There are 109 sectors (and commodities) in the original I-O tables. For the purpose of this study, we disaggregate the energy sectors and aggregate other sectors to form 35 sectors (and commodities). Specifically, the disaggregation is as follows: the coal sector is split to black coal and brown coal sectors; the oil and gas sector is separated to the oil sector and gas sector; the petroleum and coal products sector becomes four sectors – auto petrol, kerosene, LPG and other petrol; the electricity supply sector is split to five electricity generation sectors – black coal electricity, brown coal electricity, oil electricity, gas electricity and renewable electricity – and one electricity distributor – the commercial electricity sector. This disaggregation is based on the energy use data published by ABARE. Utilizing the household expenditure survey data by ABS (2004), the household income and consumption data were disaggregated to 10 household groups according to income level and labour supply was disaggregated to 9 occupation groups.

The carbon emissions data are based on the greenhouse gas emission inventory 2005 published by the Department of Climate Change and Energy Efficiency. There are two kinds of emissions: energy emissions and the other emissions. The former is mainly stationary energy emission (emissions from fuel combustion), for which the Australian Greenhouse Emissions Information System provided emission data by sector and by fuel type. We map these data into 35 sectors (and commodities) in our study. Based on this emission matrix and the absorption (input demand) matrix for industries, we can calculate the emission intensities by industry and by commodity – input emission intensities. The other emissions – the total emissions minus the stationary emissions – are treated as activity emissions and they are assumed directly related to the level of output in each industry. Based on the total output for each industry in the MAKE matrix of the I-O tables, we can calculate the output emission intensities. We assume the activity emissions by household are proportional to household consumption and, using the data on household consumption by commodity in I-O table, we can calculate the consumption emission intensities.

Most of the behavioural parameters in the model are adopted from ORANI-G, e.g. the Armington elasticities, the primary factor substitution elasticity, export demand elasticity, and the elasticity between different types of labour. The changed or new elasticities include the household expenditure elasticity, the substitution elasticities between different electricity generations, between different energy inputs and between composite energy and capital. Since we included in the model 10 household groups and 35 commodities, we need the expenditure elasticities for each household group and for each of the commodities. Cornwell and Creedy (1997) estimated Australian household demand elasticities by 30 household groups and 14 commodities. We adopted these estimates and mapping into the classification in our model. Due to the aggregation and disaggregation as well as the change of household consumption budget share, we found the share weighted average elasticity (Engel aggregation) was not unity. However, the Engel aggregation must be satisfied in a CGE model in order to obtain consistent simulation results. We adjusted (standardised) the elasticity values to satisfy the Engel aggregation.

As stated earlier, the substitution effect between different electricity generations is assumed perfect, so we assign a large value of 50 to their substitution elasticity. The substitution effects among energy input and between composite energy and capital are considered very small, so small elasticity values between 0.1 and 0.6 are commonly used in the literature. In our model, there are two levels of substitution among energy goods. At the bottom level, the energy inputs have a relatively high similarity, so we assign a value of 0.5 for substitution between black and brown coal, between oil and gas and between various types of petroleum. At the top level, we assume the substitution effect between various types of composite energy inputs is very small, and assign a value of 0.1. Similarly, we assume the cost of energy-saving investment is very high given the current technology situation and thus there is a very limited substitution effect between capital and composite energy. Consequently, we assign a value of 0.1 for this substitution elasticity.

4. Results of Policy Simulations

We have implemented three short-run carbon tax scenarios using the CGE model developed in this paper. The macroeconomic closure for all three scenarios is identical except for the level of carbon tax introduced as an exogenous shock. The Australian government has announced the introduction of a carbon tax from 1st July 2012 at the rate of $23 per tonne of CO2-e. This main policy scenario is examined in the paper with two comparable tax policies, namely $15 and $30 per tonne of CO2-e. The latter two tax levels are used merely to gauge the extent of variation of the impact of a carbon tax from the government policy stance, because in the current carbon tax debate, some commentators have advocated a lower level tax initially while the Australian Greens Party has always preferred a higher starting level for the tax. The underlying short-run macroeconomic closure assumes fixed real wages and fixed industry-specific capital stocks with endogenous employment levels and capital rentals. We also assume that the revenue raised through the carbon tax is retained by the government. To be in line with the government policy announcement, we have exempted agriculture and road transport sectors from the carbon tax.

4.1 Macroeconomic Effects

Reducing emissions in the Australian economy requires both curbing the usage of carbon intensive energy sources and using more renewable energy or switching to less polluting energy consumption. Naturally, a carbon tax is a cost to producers depending on the carbon content in their inputs and outputs. How this cost affects the economy depends on the capacity of producers to pass it on to consumers. In this context, consumers include industries in the economy and households. The competitive behaviour in the model implies that producers attempt to pass on the increased cost as much as they can to the users of their outputs in their attempt to maximize profits.

Table 1: Main Macroeconomic Effects of a Carbon Tax in Australia (percentage changes)

Variable	$15 Tax	$23 Tax	$30 Tax
Consumer price index (CPI)	0.39	0.75	1.05
Price of electricity	13.99	26.10	37.58
Nominal wage rate	0.39	0.75	1.05
Real wage rate	0.00	0.00	0.00
Real exchange rate	-0.39	-0.75	-1.05
Price of exports	0.16	0.32	0.41
Price of imports	0.00	0.00	0.00
Terms of Trade	0.16	0.32	0.41
Gross Domestic Product (GDP)	-0.35	-0.68	-0.88
Real household consumption	-0.08	-0.14	-0.18
Volume of exports	-1.51	-3.00	-3.90
Volume of Imports	0.05	0.11	0.15
BOT contribution to GDP (real)	-0.20	-0.56	-0.73
Aggregate employment	-0.54	-0.98	-1.27

Source: Projections from the model.

Table 1 shows the key macroeconomic effects of a carbon tax on the Australian economy. The first panel of the table lists the percentage changes of some of the important price variables in response to the carbon tax. It would appear at the first glance that all the prices are affected positively when a carbon tax is introduced. A $23 tax would result in a 0.75 per cent increase in the consumer price index (CPI) whereas a lower tax ($15) has a less inflationary effect overall (i.e. CPI change is 0.39 per cent). As can be seen from the projections, a $30 tax would push the CPI inflation to 1 per cent. What is most interesting here is the way the price of electricity responds to the carbon tax. Under a $23 tax we would expect the price of electricity to rise by about 26 per cent in the short run. This is not surprising given that Australia is a high energy consumer as reflected by the energy to GDP ratio of 14 per cent. Moreover, a significant proportion of electricity is still generated by burning brown and black coal.

In our simulations, nominal wages are fully indexed to the CPI and this explains the nominal wage inflation by the same magnitude of the change in consumer prices assuming real wages to be sticky. The domestic inflationary outcomes mean an appreciation of the real exchange rate and increase in the price of exports in domestic currency terms. Given that import prices are fixed by the closure assumptions, we would expect terms of trade to improve by about 0.32 per cent with the $23 tax on carbon emissions.

Many macroeconomic variables in the second panel of Table 1 confirm that a carbon tax of any magnitude would lead to a contraction of the size of the economy by a small percentage compared to the baseline. With the introduction of the carbon tax at $23 per tonne, our model projects that there would be a 2.65 per cent decline in energy consumption in the economy (see Table 2). This provides some clue to the about 0.68 per cent contraction in GDP. There are two other crucial effects working through the macro-economy other than GDP. They are real household consumption (-0.14 per cent) and the reduction in export volumes (-3.00 per cent). The decline in real consumption is lower than the reduction in GDP due to somewhat associated terms of trade improvement that tends to offset a part of deadweight losses arising from the introduction of a carbon tax. More importantly, there is a noticeable impact on employment -the proposed tax will have nearly 1 percent reduction in aggregate employment. The balance of trade will deteriorate following the projected trade outcomes which confirm the speculations that carbon tax is detrimental to the trade-exposed sectors of the economy. This basically stems from the inability of Australian exporters to pass their entire cost increases to the overseas buyers of Australia's exports.

Table 2: Selected Projections on Environmental Variables

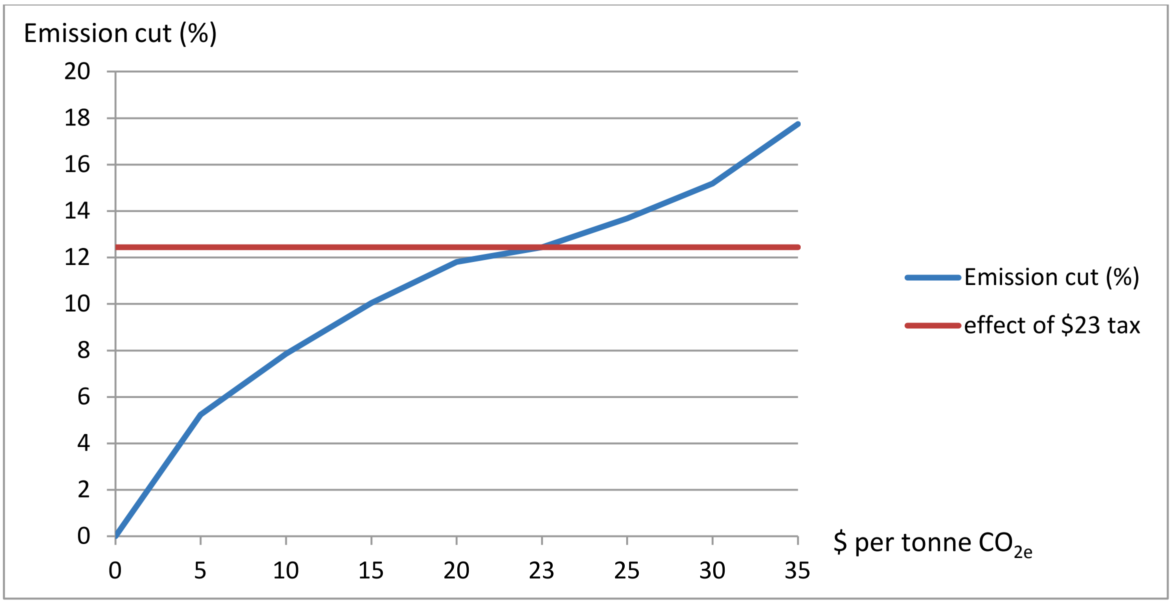
Variable	$15 Tax	$23 Tax	$30 Tax
Aggregate reduction of emissions (Megatonne)	-58.99	-73.04	-89.1
Percentage reduction of emissions	-10.05	-12.44	-15.18
Carbon tax revenue ($ billion)	4.36	6.37	7.84
Aggregate demand for energy (percentage reduction)	-1.41	-2.65	-3.73

Source: Projections from the model.

Some important macroeconomic projections relating to the environment are depicted in Table 2. A 2.65 per cent cut in demand for energy goods with the proposed tax ($23) tends to reduce Australia's aggregate emissions by about 73 Megatonnes in the initial period of its introduction. The projections with varying tax scenarios confirm that the carbon tax is an effective policy instrument - it may bring the pollution levels down as the tax works through the industrial structure of the Australian economy. The 12 per cent reduction in carbon emissions would keep Australia on track in achieving its voluntary target of emissions cut below 5 percent of 2000 levels by 2020.

Introduction of a carbon tax in Australia has attracted much attention due to the revenue generating capacity of the tax. This is viewed as a capacity of the policy to compensate losers, especially households and affected trade exposed industries. Table 2 shows that a $23 tax would raise about $6.3 billion of revenue in its first year of operation. Interpreting the tax as a marginal abatement cost, it is clear that revenue levels are quite sensitive to the cost of abatement in the economy. A $30 tax would result in $7.8 billion carbon tax revenue to the government.

Figure 2: Australia's Emission Reductions under Different Carbon Tax Levels



Source: Based on model projections.

Figure 2 illustrates the sensitivity of emission reductions to different levels of carbon tax. This curve can be interpreted as the marginal abatement cost curve. It is obvious that the carbon tax is effective at reducing emissions especially at lower tax rates. The horizontal line reflects the emission cut under $23 tax (12.4 per cent).

5.2 Effects on Sectoral Outputs

Table 3 shows the percentage changes in sectoral outputs in response to the three respective carbon tax policy scenarios. The last column of Table 3 reports the emission intensity of individual sectors that explains to a large extent the variation in sectoral outputs. In other words, there is a close correlation between output change and the emission intensity. Since the level of carbon tax burden is based on the level of emissions an industry generates, a carbon tax generally increases the cost of production more significantly for sectors whose emission intensity is high.

As can be seen from Table 3, sectoral outputs tend to contract at an increasing rate with the higher level of carbon tax imposing more stringent emission reductions. With the highest emission intensity, the two hardest hit sectors under the $23 tax are 'Electricity-brown coal', and 'Electricity-black coal'. Even though the 'Brown coal' sector has only moderate emission intensity, its output declines dramatically due to declining demand from the electricity generating sector using brown coal and reduced exports of coal. Interestingly, 'Electricity-oil' and 'Electricity-gas' sectors report positive output change despite their high carbon intensity in production. This may be due to the even higher cost of electricity generation by burning coal in the face of a carbon tax. The policy causes substitution in favour of these sectors at the expense of the most pollutive coal-powered power generation. As would be expected, ‘Electricity-renewable’ appears to be the biggest winner from the carbon tax. Overall, the distributer of electricity – ‘Commercial Electricity’ – contracts due to reduction in electricity demand in response to an increase in the price of electricity to final consumers.

Table 3: Sectoral Output Changes in Response to Carbon Tax (percentage change)

	Industry	$15 tax	$23 tax	$30 tax	Emission Intensity[1]
1	Agriculture, forestry & fishing	-0.29	-0.63	-0.75	0.14
2	Black coal	-0.52	-0.88	-1.11	0.19
3	Brown coal	-14.98	-26.42	-35.9	1.65
4	Oil	-0.07	-0.11	-0.15	0.18
5	Gas	-0.26	-0.40	-0.53	0.89
6	Other mining	-0.30	-0.48	-0.68	0.19
7	Food, beverages & tobacco	-0.59	-1.82	-1.46	0.06
8	Textile, clothing & footwear	-0.58	-1.02	-1.45	0.05
9	Wood, paper & printing	-0.41	-0.76	-1.02	0.06
10	Automotive petrol	-0.15	-0.03	0.00	0.28
11	Kerosene	-0.56	-0.81	-1.06	0.75
12	Liquefied petrol	-0.74	-1.02	-1.44	0.71
13	Other petroleum & coal products	0.21	0.42	0.59	0.07
14	Chemical products	-1.49	-2.54	-3.47	0.23
15	Plastic & rubber products	-0.86	-1.57	-2.09	0.18
16	Cement	-0.77	-1.22	-1.59	0.44
17	Iron & steel	-2.46	-4.09	-5.56	0.28
18	Other metal products	-1.51	-2.46	-3.30	0.32
19	Other Manufacturing	-0.63	-1.15	-1.61	0.01
20	Electricity-black coal	-6.14	-8.34	-10.26	19.40
21	Electricity-brown coal	-8.79	-18.1	-27.84	25.78
22	Electricity-oil	4.37	7.28	9.60	10.85
23	Electricity-gas	2.01	3.38	4.44	8.76
24	Electricity-renewable	8.57	11.84	13.87	0.00
25	Commercial electricity	-4.22	-7.06	-10.18	0.00
26	Gas distribution	-0.43	-0.76	-1.02	0.39
27	Water & sewerage services	-0.29	-0.52	-0.67	0.01
28	Construction services	0.01	0.02	0.04	0.01
29	Trade services	-0.27	-0.51	-0.69	0.00
30	Accommodation &restaurants	-0.76	-1.35	-1.77	0.02
31	Road transport services	-0.48	-0.92	-1.23	0.04
32	Other transport services	-0.66	-1.16	-1.59	0.03
33	Communication services	-0.18	-0.34	-0.46	0.00
34	Public services	-0.30	-0.54	-0.72	0.01
35	Other services	-0.18	-0.34	-0.45	0.00

Source: Output projections are from the model. 1. Note: 1. Emission intensity is calculated from the database of the model and it is defined as emissions (kilo tonnes) per million of dollars.

The output adjustments of remaining sectors largely depend on their inter-industry linkages, use of emission-intensive inputs, and the importance of electricity in their input mix. Some sectors are highly export oriented and their growth is hindered by their limited ability to pass the increased cost to customers overseas. Despite the significant contraction in the output of the black coal generation sector, the output of 'Black coal' declines only by a small percentage (0.88 per cent). Due to the substitution of black coal for brown coal in other economic activities as well as in power generation, the output reduction in 'Black coal' is rather modest. The 'Iron & steel' sector suffers a significant output loss due to the cost increases and deterioration of its competitive advantage.

Table 4: Effects of Carbon Tax on Broad Employment Groups (percentage change)

Employment group	$15 Tax	$23 Tax	$30 Tax
Managers &administrators	-0.59	-1.08	-1.39
Professionals	-0.46	-0.82	-1.09
Associate professionals	-0.50	-0.89	-1.17
Trade persons	-0.56	-0.99	-1.27
Advanced clerical	-0.48	-0.86	-1.15
Intermediate clerical	-0.53	-0.96	-1.25
Intermediate production	-0.84	-1.48	-1.91
Elementary clerical	-0.46	-0.85	-1.13
Labourers	-0.59	-1.18	-1.41

Source: Projections from the model.

Table 5: Effect of Carbon Tax on Employment by Sectors (percentage change)

	Industry	$15 tax	$23 tax	$30 tax
1	Agriculture, forestry & fishing	-0.56	-1.22	-1.45
2	Black coal	-1.92	-3.15	-4.00
3	Brown coal	-39.93	-53.15	-63.09
4	Oil	-0.58	-0.98	-1.32
5	Gas	-1.80	-2.71	-3.60
6	Other mining	-0.87	-1.43	-1.97
7	Food, beverages & tobacco	-0.94	-2.71	-2.30
8	Textile, clothing & footwear	-0.88	-1.56	-2.21
9	Wood, paper & printing	-0.64	-1.21	-1.62
10	Automotive petrol	-0.13	0.02	0.05
11	Kerosene	-0.61	-0.89	-1.17
12	Liquefied petrol	-0.91	-1.23	-1.81
13	Other petroleum & coal products	0.24	0.47	0.66
14	Chemical products	-2.52	-4.25	-5.74
15	Plastic & rubber products	-1.13	-2.05	-2.73
16	Cement	-1.02	-1.60	-2.05
17	Iron & steel	-3.99	-6.51	-8.67
18	Other metal products	-2.33	-3.79	-5.04
19	Other Manufacturing	-0.85	-1.57	-2.19
20	Electricity-black coal	0.82	3.87	5.65
21	Electricity-brown coal	-2.51	-7.84	-13.23
22	Electricity-oil	12.73	22.97	32.54
23	Electricity-gas	14.98	24.47	32.54
24	Electricity-renewable	43.04	67.41	87.48
25	Commercial electricity	-11.6	-17.37	-22.78
26	Gas distribution	-5.94	-10.05	-13.03
27	Water & sewerage services	-0.67	-1.20	-1.53
28	Construction services	0.04	0.06	0.10
29	Trade services	-0.35	-0.67	-0.90
30	Accommodation & restaurants	-1.12	-1.97	-2.55
31	Road transport services	-0.69	-1.33	-1.76
32	Other transport services	-1.22	-2.14	-2.91
33	Communication services	-0.41	-0.76	-1.02
34	Public services	-0.32	-0.57	-0.76
35	Other services	-0.22	-0.40	-0.53

Source: Projections from the model.

5.3 Effects on Employment

Australia has been enjoying a fairly low unemployment rate in recent years and the opponents to a carbon tax argue that the additional tax burden on the economy would result in employment losses in many sectors. It is true that the trade exposed sectors are likely to contract more relative to non-trading sectors in response to the carbon tax and substantial employment losses may occur in those sectors.

Table 4 shows the employment impact of the carbon tax on different groups of employment in the Australian economy. The tax induces production changes throughout the economy and all employment groups are shown to bear the burden with negative effects to varying magnitudes. These employment projections in fact illustrate how the aggregate employment reduction at the macro level (see Table 1) is shared across employment groups. With a $23 tax, the most severe job losses are projected to be in 'Intermediate production', and 'Labourer' groups followed by 'Managers & administrators'. The remaining groups show somewhat less severe job losses. The occupational employment impact is different with a lower carbon tax ($15). This probably reflects changes in the industry structure of the economy in the face of moderate cost increases. Projections in Table 5 display that blue-collar workers (labourers) are more severely affected. This is consistent with the fact that industries that suffer from the carbon tax (e.g. coal mining and coal electricity) tend to have a higher blue-collar labour force.

Sectoral output changes as reported in Table 5 indicate that a majority of sectors experience employment losses and some selected sectors gain employment. Notice that sectors which lose employment are subject to a higher burden of carbon tax due to their high emission intensity. They also employ a significant proportion of blue-collar workers. Overall, sectoral employment changes more rapidly compared to macro level (aggregate) change in employment in the economy and the latter represents the weighted outcome of the economy.

5.4 Effects on Households

Households will experience changes in the relative prices of commodities as industries incorporate carbon tax into their production costs. The exact impact of a carbon tax on prices of particular commodities depends on many factors and may change as new production practices evolve such as substitution towards renewable energy sources. As far as households are concerned, the increased prices of carbon-intensive commodities due to a carbon tax will have a disproportionate impact on those who use more carbon-intensive commodities. Carbon pricing also affects factor prices in a general equilibrium framework. Households may experience income reductions[4] with a decrease in the price of factors of production on which their income is mainly relied.

[4] In public finance literature the direct impact on prices of commodities of tax on households is known as a uses of income impact (pass forward effect) whereas the factor price effect is known

Table 6 reports the effects of a $23 carbon tax on households assuming that the tax is fully passed forward and backward through commodity prices and factor prices. The real household consumption of each decile (income group) is projected to respond to the tax negatively and the degree of change varies from -0.02 per cent (poorest households) to -0.14 per cent (richest households). Generally, the low income households spend a more than average household share of their income on energy-intensive goods and hence find it difficult to reduce their real consumption whereas rich households can adjust to the relative price shifts and reduce their consumption more, especially reducing consumption of energy-intensive goods. This is clearly

Table 6: Effects of $23 Carbon Tax on Households

Household Deciles[1]	Real Consumption (percentage change)	Energy Consumption (percentage change)	Percentage Tax Burden[2]	Equivalent Variation (EV) (A$ million)
1st ($11,315)	-0.02	-0.26	3.6	-5.7
2nd ($21,207)	-0.02	-0.32	2.0	-8.4
3rd ($30,173)	-0.02	-0.24	1.6	-8.4
4th ($40,188)	-0.04	-0.41	1.4	-23.6
5th ($54,599)	-0.05	-0.61	1.1	-37.0
6th ($67,593)	-0.06	-0.71	1.1	-54.5
7th ($82,355)	-0.07	-0.87	0.9	-73.3
8th ($100,144)	-0.09	-1.00	0.8	-104.1
9th ($125,872)	-0.11	-1.20	0.7	-144.0
10th ($205,259)	-0.14	-1.62	0.6	-293.4
Economy aggregate	-0.14	-2.65	0.9[3]	-752.3[4]

Source: Projections from the model.

Notes: 1. Average annual income for each decile is in brackets. 2. Percentage tax burden is estimated by taking the ratio of new expenditure after tax to average household income in each decile. 3. This is the average household burden with average income of $72,800. 4. This is the total EV for the economy.

supported by the changes in energy consumption by each household group as shown in the third column of Table 6. For example, the richest households may reduce energy consumption by 1.62 per cent while poorest households can cut their energy consumption only by 0.26 per cent in response to the tax. This partly reflects the affordability of rich households to acquire more energy-saving appliances as well as switching towards low cost heating and power generation alternatives such as solar systems.

as a sources of income effect (pass backward effect). See for example, Atkinson and Stiglitz (1980).

The second last column of Table 6 shows the percentage tax burden on each income decile as a result of imposing the $23 carbon tax in Australia. Most notably, the tax burden is unequally distributed among different household groups with low-income households carrying a relatively higher burden. This regressivity of the carbon tax is a major concern on equity grounds as the policy hits hard the low income segment of the community and any compensation to ease the burden needs to take this finding into consideration. Compared to the average household impact (0.9 per cent burden), the poorest four deciles show a much higher burden of tax (3.6 to 1.4 per cent). These groups are generally vulnerable in the society and may include pensioners, most of the unemployed who receive various forms of government welfare and low income earners.

The last column of Table 6 shows the summary of the welfare impact in terms of estimates of equivalent variation (EV) in dollar terms. The EV represents the change of welfare in absolute monetary terms (in terms of income) that eventuates from the change in domestic prices in response to the carbon tax. The absolute welfare loss is greater for higher income household groups and Australia is estimated to experience an aggregate loss of $752.3 million. This represents about 0.6 per cent of Australia's GDP.

In Table 7 we analyse the household impact further by incorporating the 2003-04 household expediture survey data into our general equilibrium results. As a result of the rising costs of living after the tax, the annual dollar burden of carbon tax across household groups varies from $409 (poorest) to $1150 (richest) while the average income families are expected to incur $685 new expenditure. For an average household, approximately 50 per cent of this extra expenditure ($345) would be due to the increased cost of electricity. This share would be even higher (56 per cent) for the poorest household group (decile 1). Translated into weekly impact, the carbon tax on the Australian average household is expected to rise by $13.18 and the contribution of electricity cost towards this is projected to be $6.64. The Treasury modelling suggests that the

Table 7: Net Impact on Households of a $23 per Tonne Carbon Tax ($)

	Decile 1 (poorest)	Decile 2	Decile 3	Decile 4	Decile 5	Decile 6	Decile 7	Decile 8	Decile 9	Decile 10 (richest)	Average household
Annual Impact:											
Impact on cost of electricity	228	254	284	309	325	362	371	396	415	509	345
Impact on all other goods and services	181	160	202	254	302	352	398	433	505	641	340
Total impact	409	414	486	563	627	714	769	829	920	1150	685
Weekly Impact:											
Impact on cost of electricity	4.39	4.90	5.46	5.93	6.24	6.97	7.14	7.61	7.98	9.80	6.64
Impact on all other goods and services	3.48	3.07	3.89	4.90	5.82	6.76	7.65	8.34	9.71	12.33	6.54
Total impact	7.87	7.97	9.35	10.83	12.06	13.73	14.79	15.95	17.69	22.13	13.18
Percentage Tax burden	3.6	2.0	1.6	1.4	1.1	1.1	0.9	0.8	0.7	0.6	0.9

Source: Model projections and Household Expenditure Survey 2003-04 (ABS, 2004).

average weekly household budget impact would be a $9.90 rise per week with the weekly increase in electricity cost accounting for $3.30[5].

6. Concluding Remarks

Policy makers are required to be well informed about the possible effects of environmental policies such as carbon tax, which will have far-reaching implications. A computable general equilibrium model with particular details of tax policies, energy uses, and emissions is the most appropriate methodology to quantify the economy wide impact of implementing a carbon tax policy. In this paper we have described the formulation of a 35-sector general equilibrium model of the Australian economy which was particularly designed for analysing the effects of a carbon tax. The comparative static nature of the model made it well-suited for singling out the impact of carbon tax policies in a counterfactual framework in short run. The model was simulated with the proposed $23 per tonne tax enabling our results to be viewed as an alternative to Treasury modelling outcomes which have been used by the government for designing the carbon tax legislation. The analysis reported here also gives an opportunity for understanding the differential impact of the tax either by adopting higher or lower level of tax to what is proposed by the government. To this end we have simulated $15 and $30 tax in addition to $23 tax for comparison.

Our general equilibrium calculations show that an environmentally valuable reduction of carbon dioxide emissions in Australia through a carbon tax is achievable without major disruptions to the Australian economy. In particular, the government's target of reducing Australia's emissions to 5 percent below 2000 levels by 2020 seems plausible with a $23 tax with minimum adjustments.

The carbon emission reduction comes at a modest cost to the economy in terms of its GDP reduction arising from distortions created by the carbon pricing mechanism. Consistent with the Treasury findings, our model projects that Australia's real GDP may decline by about 0.68 per cent after the introduction of a $23 tax on carbon dioxide emissions. The inflationary effect of the tax is fairly small as measured by the change in consumer price index. The tax would result in an inflationary effect of 0.75 per cent in consumer prices. Our model predicts a 26 per cent increase in the price of electricity. This is not surprising as Australia's electricity generation is heavily dependent on carbon-intensive black and brown coal, which attracts a large amount of carbon tax burden. Our result is, however, one significant contrast to the Treasury projections (10 per cent increase).

Electricity generating sectors will be negatively affected, especially those which are heavy fossil fuel users. Due to substantial emissions by black and brown coal generators, these two sources of electricity will become fairly expensive with a carbon tax in place and will face a significant decrease in demand. However, our model projects a significant increase in electricity generation by renewable energy, gas and oil using generators. Our

[5] These estimates are based on a $20 carbon tax modelled by the Treasury (The Treasury, 2011).

projections are short-run outcomes but the indication is that these generators will do even better in the long run.

The distributional implications of the carbon tax are important for Australian households and our household analysis shows that low-income households need special attention. Even though we have not examined in this paper the forms of compensating the households to ease the burden, our model is best-suited for such analysis. While we reserve this to be a rigorous analytical subject in another paper, the findings of this paper suggests that an annual lump-sum payment of $685 to each and every household in Australia would be a reasonable and politically neutral strategy to win public support.

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