The Environmental and Employment Effect of Australian Carbon Tax

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***Abstract*—The paper employs a computable general equilibrium (CGE) model with an environmentally-extended Social Accounting Matrix (SAM) to simulate the effects of a carbon tax of $23 per tonne of carbon dioxide on different economic agents, with and without a compensation policy. According to the simulation results, the carbon tax can cut emissions effectively, but will cause a mild economic contraction. The proposed compensation plan has little impact on emission cuts while significantly mitigating the negative effect of a carbon tax on the economy. The effect on various employment occupations is mildly negative, ranging from -0.6% to -1.7%, with production and transport workers worst affected.**

***Index Terms*—Carbon tax, CGE modelling, macro economy, environmental effect, employment effect.**

I. Introduction

Although Australia' s greenhouse gas emissions are relatively low – accounting for around 1.5% of global carbon emissions, its emissions per capita are the highest in the world (reference [1]). The high emissions per capita in Australia are partly due to a small population and abundant cheap energy resources, particularly brown and black coal, which have very high emission intensity. The Gillard government has committed to reducing carbon emissions by 80% below 2000 levels by 2050 and announced that it will introduce a carbon tax from July 1st 2012.

The government's proposal triggered strong resistance from Opposition parties and various interest groups. They claim that a carbon tax will cause a large economic contraction, high unemployment, higher electricity prices and the demise of the coal industry. Certainly, public opinion about a carbon tax is divided. Amid anti- and pro- carbon tax rallies and demonstrations, speculation about the effects of the proposed tax varies widely.

To support the carbon tax proposal, the Australian Treasury has undertaken comprehensive modelling. The Treasury has employed a suite of different models, including two CGE models, one input-output model and a number of micro models for the electricity and road transport sectors. The results from this modelling depend on the parameters and assumptions used (as with all models), but given the intricacy and complexity of the modelling, these are not easy to articulate and evaluate. Similarly, the results will depend on the degree of integration and compatibility of the different models, again, matters not assessed easily. Perhaps as a result of this, and certainly because of the way the politics has played out, Australians are sceptical about the modelling results, with the Opposition leader stating openly that the carbon tax proposal is based on a lie.

In this paper we adopt a different approach. To single out the effects of a carbon tax, we constructed a single country static CGE model. In companion, an environmentally-extended micro Social Accounting Matrices (SAM) is developed. Based on the simulation results, this paper purports to uncover the short run implications of a carbon tax policy for carbon emission reduction, the macro-economy, different sectors, occupation groups, and household income deciles.

The balance of the paper is organised as follows. Section II describes the model structure and database for the simulations. Section III presents and discusses the simulation results with special reference to different economic groups. Section IV concludes the paper.

II. Modelling Framework

The effect of a carbon tax is a well researched topic internationally. Notable research includes references [2]-[8]. A comprehensive review of international modelling literature is given in reference [9].

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 [5]. The comparative static nature of ORANI-G helps to single out the effect of carbon tax policies while keeping other factors being equal. 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 multi-households version of ORANI-G.

Overall, the production function is a five-layer nested Leontief-CES function. As in the ORANI model, the top level is a Leontief function describing the demand for intermediate inputs and composite primary factors and the

Manuscript received March 6, 2014; revised May 9, 2014.

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DOI: 10.7763/IJSSH.2015.V5.510

rest is various CES functions at lower levels. However, we have two important modifications to demand functions for electricity generation and energy use.

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 the model computes stationary emissions 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.

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 [10]. 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 [11], 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 emissions (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 the 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. Reference [12] 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 inputs 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, 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. There are two levels of substitution among energy goods in our model. 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.

III. Simulation Analysis

The purpose of this study is to gauge the impact of an Australian carbon tax policy on the environment, the economy and various economic agents, so the level of carbon tax is chosen to reflect the proposed government policy, namely, $23 per tonne of carbon dioxide emissions with the exemption of agriculture, road transport, and household sectors. However, the government compensation plan is quite complicated. There are various levels of compensation to a number of industries such as manufactures and exporters. For household, the government proposed reform of taxthresholds and various family tax benefits like clean energy advance, clean energy supplement and single income family supplement. Not to complicate the study, we only impose a simple revenue-neutral compensation for households: all carbon tax revenue is transferred in lump sum equally to all household deciles.

This study simulates and compares two scenarios: carbon tax only and with compensation. This study is mainly concerned with the short run effects, so a short-run macroeconomic closure is assumed, e.g. fixed real wages and capital stocks, free movement of labour but immobile capital between sectors, and government expenditure to follow household consumption. Unless specified, all projections reported in this paper are shown in percentage changes.

The simulation results are reported in terms of emission reduction and carbon tax revenue, GDP and GNP, payment to primary factors, government income and expenditure, real household consumption and international trade, and employment by occupation group and by sector, as shown in Fig. 1- Fig. 3.

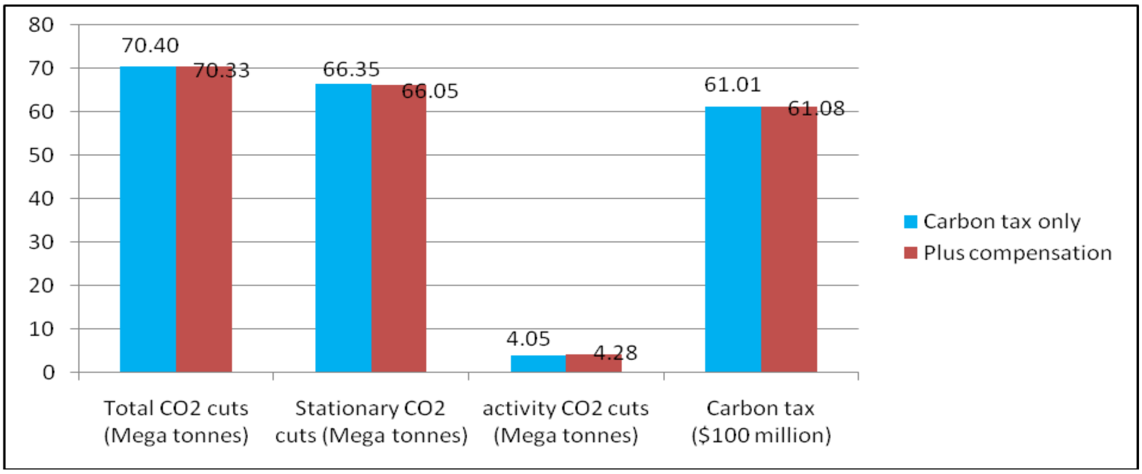

Fig. 1. Emission reduction and carbon tax revenue.

A glance at Fig. 1 manifests that a $23 carbon tax is very effective. The total carbon emissions decreased by about 70 mega tonnes. Given Australia's emissions base of 587.1 mega tonnes in 2004-05, this indicates a 12% reduction rate. In the mean time, the government can collect around $6.1 billion in tax revenue, which can improve the government budget in the tax only scenario or relieve consumer's burden in the compensation scenario. A careful observation can reveal more detailed feature.

First, the stationary emission cuts are the main contributor to the effectiveness of the carbon tax policy. This looks odd given the emission accounting data. Disaggregating total Australian emissions into stationary emissions and other emissions (or activity emissions), we find the size of activity emissions is bigger: 275.3 mega tonnes for stationary emissions and 311.8 mega tonnes for activity emission. Why does the policy lead to more stationary emission cuts? The features of policy design in our simulation matter much.

One is that, the designed carbon tax policy tried to mimic the proposal of the government by exempting agriculture, transport and household sectors. These three sectors are big contributors to activity emissions – the agriculture sector accounts for 149.4 mega tonnes, households for 54.6 mega tonnes and road transport for 26.3 mega tonnes. The exclusion of these three sectors makes the activity emission reduction less effective.

The other is that the carbon price for both stationary emissions and activity emissions is the same. Given the smaller base of inputs (e.g. different types of fuels) accounting for stationary emissions compared with thetremendously larger output base for activity emissions, the intensity for stationary emissions should be much bigger than that for activity emissions. With the same carbon price, the higher stationary emission intensity means higher production cost and the industry will respond by reducing production more and thus reducing emissions more. As a result, the policy will work more efficiently on stationary emissions.

Second, in comparing both scenarios, the compensation plan seems to have little impact on carbon emission reduction. It is arguable that, while a carbon tax will reduce carbon emissions by raising the prices of carbon intensive goods like coal and electricity, a compensation policy will offset the carbon reduction through increased demand for carbon intensive goods. Countering this claim, the total emission reduction decreases only very insignificantly from 70.40 mega tonnes in the carbon tax only scenario to 70.33 mega tonnes in compensation scenario. This result may indicate that, under a carbon tax (with or without a compensation policy), consumers will shift their consumption from emission-intensive goods towards more environmental friendly goods. The change of consumers' attitude is further evident when we look into the stationary and activity emissions under two scenarios. It is apparent that the stationary emissions decrease under the compensation scenario while the activity emissions increase. Since we assume the activity emission intensity is fixed in the model, activity emissions have to rise as total output increases in response to the increased household demand under the compensation plan. The decrease in stationary emissions implies that fewer emission-intensive inputs are used and less emission-intensive outputs are produced. These movements of both emissions largely cancelled out each other, hence it is understandable why the total emission reduction is almost the same for both scenarios.

Third, the carbon tax revenue the government can collect moves in the direction opposite to that of emission reduction. As the carbon emission reduction decreases slightly in the compensation scenario, carbon tax revenue increases slightly from $6.101 billion to $6.108 billion. This opposite movement can be easily understood. Given a fixed carbon tax rate, the amount of carbon tax revenue is determined by the base of a carbon tax (or emissions base). The higher emission cuts means smaller carbon tax base and thus less tax revenue. This result tells us that carbon tax revenue can be another indicator of the effectiveness of carbon tax policy (from the point of view of environment): the more carbon tax revenue the government collects, the less efficient the carbon tax policy will be.

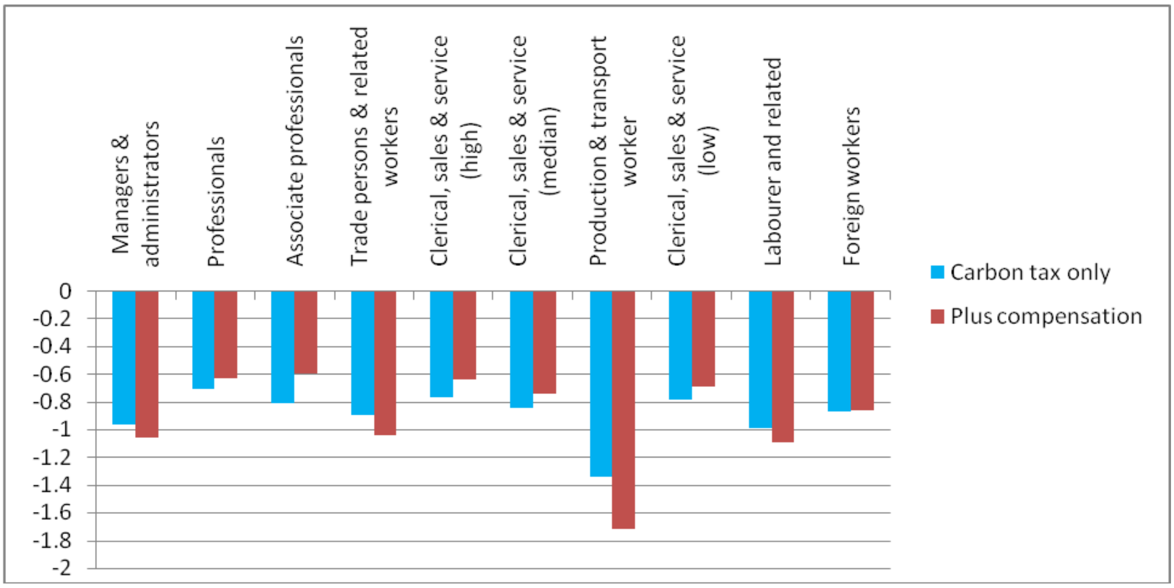

Fig. 2. Percentage change in employment by occupation.

The employment effects are illustrated by change in employment by occupation and by sector respectively. Domestic employment is put into 9 occupations in our model. The percentage changes of employment for each group are shown in Fig. 2.

Understandably, the employment effects are negative for all occupation groups under all scenarios due to the contraction of the economy in the presence a carbon tax. However, the employment impact on all occupation groups is relatively small, ranging from -0.6% to -1.7% decrease. Production and transport workers are the worst affected. Apparently, this group is closely related to emission or energy intensive sectors such as electricity, mining, manufacturing and transportation. In the face of a carbon tax, these sectors experience significant contraction and may lay off large number of workers. Similarly, the close link with emission intensive sectors explains the around 1% decrease in employment for the second tier of most affected occupation groups, e.g. managers & administrators, trade persons & related workers, and labourers.

Interestingly, for those worst affected groups, the compensation policy will deteriorate further their employment prospects. This may be the result of consumers' taste changing under a carbon tax. As consumers further substitute away from carbon intensive goods to low carbon commodities under the compensation policy, low carbon sectors expand at the expense of emission intensive sectors. As a result, occupations more closely associated with emission intensive sectors would be worse off. For the same reasoning, the rest of the groups are less affected and the situation improves under the compensation scenario.

The employment by sector shown in Fig. 3 reveals a different aspect of carbon tax impact. For some sectors, the changes in employment are very large. It decreases by 53% for the brown coal industry, increases by around 64% in the renewable electricity industry and 23% in the gas electricity sector. These changes are several times higher than the corresponding changes in sectoral real output. The large change in employment may be explained as follows. As the real wage is rigid in the short run, firms will not incur too much cost by employing more staff during an expansion and have to lay off more workers in order to reduce production costs during a contraction.

Since the large decrease in employment in the brown coal sector will be largely cancelled out by the large employment increase in the gas electricity and renewable electricity sectors, the overall unemployment effect will not be large. However, this is based on the assumption that workers can move freely between sectors and between different regions. In reality, workers may have difficulty doing so. In this case, there would be large structural unemployment when the economy is shifting from high carbon to low carbon production. To reduce structural unemployment, government assistance is much needed.

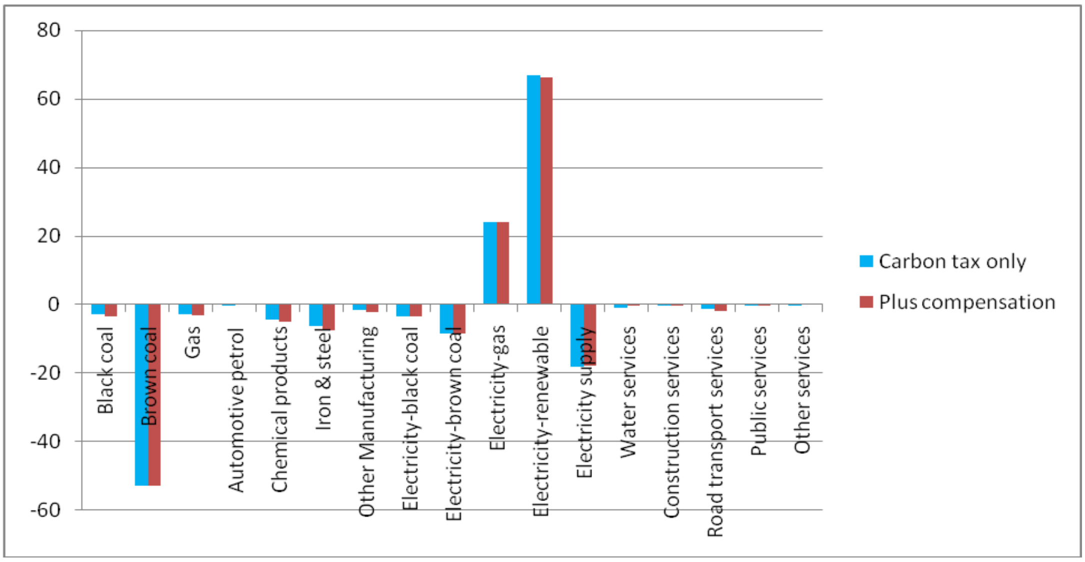

Fig. 3. Percentage change in employment by sector.

IV. Conclusions

To gauge the impact of a carbon tax in Australia, we constructed an environment-extended micro SAM and built a CGE model for Australia. Two scenarios are analysed in the paper. One is a $23 per tonne carbon tax with the exemption of agriculture, land transport and household sectors. The other is, on the top of carbon tax scenario, the tax revenue is fully and equally transferred to household deciles in lump sum. Overall, the simulation results show that a carbon tax of $23 per tonne carbon dioxide can cut emissions effectively, but cause mild economic contraction, and that the proposed compensation plan has little impact on emission cuts while mitigating the negative effects of a carbon tax on the economy.

Specifically, the environment is the biggest winner under both scenarios – around 12% emission reduction can be achieved in the short run. Since the biggest activity emission contributors (e.g agriculture, land transport and household sectors) are exempted from the carbon tax, the total emission cuts are achieved mainly through reductions in stationary emissions. The sectoral analysis shows that black coal electricity and brown coal electricity are the main contributors to emission reductions, accounting for around ½ and ¼ respectively.

Although both the nominal GDP and GNP demonstrate substantial growth, the economy contracts mildly according to real GDP and real GNP under a carbon tax while the real GNP registers significant positive growth under the compensation policy. The return on capital and land decreases substantially, but the return on labour only drops slightly under the tax only scenario and increases significantly under the compensation policy, which may be due to the rigidity of real wages in the short run. The government is a winner in both scenarios. In the absence of compensation, the government's fiscal position improves substantially, but even with compensation, government revenues increase by more than its expenditures. Households are affected negatively, but marginally, while importation benefits slightly under the tax only policy. However, under the compensation policy, they both benefit significantly. Exporters are one of the biggest losers, with an almost 3% drop in real exports in the tax only case and a more than 6% drop in the compensation scenario.

At sectoral level, although the large decrease in employment in the brown coal may be cancelled out by the spectacular demand for labour in the renewable electricity and gas electricity sectors, possible structural unemployment requires the attention of the policy makers. The effect on occupational employment is mildly negative, ranging from -0.6% to -1.7%, with the production and transport workers worst affected.

The limitations of the study largely lie in the underlying features of the model. The model we developed is a static model in which capital is assumed fixed. This assumption may lead to the overstatement of the impact of a carbon tax. However, since inflexibility of capital is indeed the central feature of a short-run situation, overstatement is not a serious problem in the present analysis. Nevertheless, a dynamic model may be essential to avoid any overstatement in a long run simulation.

Acknowledgement

The authors would like to acknowledge funding from the Australian Research Council under Discovery project DP0986306.

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