Border Adjustments under Unilateral Carbon Pricing: Are they Warranted in the Case of Australian Carbon Tax?[1]

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Abstract

In the absence of a global agreement to reduce emissions, Australia has adopted a carbon tax unilaterally to curb its own emissions and to counter climate change. During the debate prior to passing the carbon tax legislation, there were concerns about the challenge that Australia's emissions intensive and trade exposed (EITE) industries may face having to experience decreasing international competitiveness due to the unilateral nature of the tax and hence the potential for carbon leakage. Domestic climate policies to limit carbon emissions can put extra pressure on industries that use emission-intensive energy sources in their production leading to cost differentials between domestic production and production in countries where carbon emissions are not constrained. It has been argued that such climate policy differences could place Australian industries at a competitive disadvantage in both home and foreign markets The potential adverse impact on Australia's competitiveness and seemingly inevitable carbon leakage have been used by opponents to the climate policy in order to undermine the carbon pricing strategy in Australia. Some have argued in favour of introducing border adjustments to make a levelled playing field with international competitors in a carbon constrained world.

In order to address these concerns, this paper explores the border adjustment policies to complement the domestic carbon regulation in Australia using the multi-sector, multi-country computable general equilibrium (CGE) modelling approach. In particular we use the GTAP-E model which has a detailed specification of energy substitution possibilities and carbon emissions accounting. The analysis reported in the paper is based on GTAP version 8 data base. We consider four border adjustments: border adjustments on imports (green tariffs) based on domestic emissions; border adjustments on exports via a rebate for exports; domestic production rebate; and full border adjustment on both exports and imports. We compare the numerical simulation results of these scenarios with no border adjustments scenario from the standpoint of welfare, international competitiveness, and carbon leakage. In line with most of the international findings of border adjustment measures in climate policy analysis, the results reveal that their effects towards easing the negative impact on Australia's EITE sectors are fairly small. The paper concludes with the consideration of whether the border adjustments are warranted in the Australian case.

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1 Introduction

Australia has adopted a carbon tax unilaterally to curb its own emissions and to counter climate change even though it accounts for a small proportion of global emissions. During the debate prior to passing the carbon pricing legislation, there were concerns about the challenge that Australia's emissions intensive and trade exposed (EITE) industries may face having to experience decreasing international competitiveness due to the unilateral nature of the tax and hence the potential for carbon leakage. Domestic climate policies to limit carbon emissions can put extra pressure on industries that use emission-intensive energy sources in their production leading to cost differentials between domestic production and production in countries where carbon emissions are not constrained. It has been argued that such climate policy differences could place Australian industries at a competitive disadvantage in both home and foreign markets.

Another concern is the carbon leakage which generally occurs due to increase in emissions in countries without strong climate policies when countries with climate policies reduce emissions. Such carbon leakage may take place through three specific channels. First, industries in the carbon-constrained country can lose international market shares through decrease of exports and increase of imports to the benefit of carbon-unconstrained competitors. This is known as the 'short-term competitiveness channel'. Second, stringent climate policy at home may reduce returns on investment and hence industries may relocate to countries where less stringent emissions control exists with higher returns. This is the investment channel of carbon leakage. Third, there is a fossil fuel price channel where reduction in global energy prices as a result of reduced demand for fossil fuel based energy in carbon-constrained countries triggers higher energy demand and hence emissions elsewhere, particularly in large non-constrained developing countries.

The potential adverse impact on Australia's competitiveness and seemingly inevitable carbon leakage has been used by opponents to undermine the carbon pricing strategy in Australia. Similar reasoning was also used in defence of postponing the ratification of the Kyoto Protocol by Australian governments. Determining the extent and nature of competitive disadvantage and potential carbon leakage is important for Australia to sustain its climate policy through carbon pricing. It is also equally important to examine the possible measures to counter decrease in competitiveness and carbon leakage resulting from carbon pricing if they are affecting the Australian economy in general and EITES industries in particular.

While border adjustment has been proposed as a possible countermeasure in the policy debate in Australia, the impact of adopting border adjustments and the empirical question as to whether they are in fact warranted in the Australian case has not been widely analysed. The exceptions are Saddler et al. (2006), which examined the issue in a rather broad framework without a formal model and Clarke and Waschik (2012), discussed below.

In this paper we use a multi-sectoral, multi-country computable general equilibrium (CGE) model, namely GTAP-E model, to simulate the impact of different border adjustment measures (BAMs) and compare them with no border adjustment outcome under the carbon tax. In particular, four BAMs are evaluated using the GTAP-E model: (1) border adjustment on exports; (2) border adjustment on imports; (3) border adjustment through production rebate (subsidy) to all domestic producers; and (4) full border adjustment (both exports and imports).

The rest of the paper is organised as follows. Section 2 briefly reviews previous climate change policy related studies on border adjustments. Section 3 briefly describes the GTAP-E model and data used in the present analysis. Section 4 outlines the emissions intensity and trade exposure of Australian industries. The basis of the BAMs used in the paper is explained in section 5. Section 6 presents results and discusses the major findings from different border adjustment measures that have been simulated. Section 5 concludes the paper.

2 Literature on Border Adjustments

There is a growing body of literature on the issue of using BAMs to alleviate the decrease in competitiveness and carbon leakage due to adopting a particular carbon pricing strategy. Climate change related BAMs are primarily proposed to restore competitiveness of the domestic economy and to combat carbon leakage while promoting deeper reductions in domestic emissions. Such policies are also considered as incentives to other countries to participate in an international effort to reduce emissions. Apart from winning the support of domestic industry lobby groups, unilateral BAMs are to some extent protective trade measures in climate policies that may induce political repercussions with retaliation, harm international trade relations and may be subject to challenge by the World Trade Organisation (WTO). Hence prior to introducing BAMs it is important for a country to gauge the potential costs and benefits of such measures and to demonstrate whether they deliver the expected economic and environmental outcomes.

CGE models have been used over the last decade to establish the economic and environmental effectiveness of adopting different BAMs such as export rebates, carbon or ‘green’ tariffs, production rebates and forcing importers to surrender carbon allowances in a cap-and-trade system. Mckibbin and Wilcoxen (2009) used the G-Cubed model to examine how large green tariffs (i.e, import border adjustments) would need to be to offset the costs of adopting climate policies, and whether the tariffs are effective in combating competitive disadvantage and reducing carbon leakage. Their study focussed on the United States and Europe under various climate policy scenarios. They found that the effects of such tariffs would be small in protecting the domestic import competing sector, and would reduce leakage very modestly. Bernard and Vielle (2009), in analysing the EU emissions trading system (ETS), found that carbon leakage may affect some specific sectors while the aggregate impact would be rather small. Kuik and Hofkes (2010) also explored some implications of BAMs in the EU ETS and concluded that some sectors may benefit, but from and environmental point of view, BAMs are not a very effective measure.

Fischer and Fox (2009) compared the effects of four BAMs (a border tax on imports, a border rebate for exports, full border adjustment, and a domestic production rebate) in a setting of a unilateral emissions pricing scheme for the US and Canada. They illustrated the results for different energy-intensive sectors in the two economies and found that such policies have varying, but rather small, impacts. According to their findings, BAMs are ineffective instruments for improving the competiveness reduced by emissions control policies and for tackling leakage effects. Domestic production rebates were preferred to other alternatives.

Alexeeva et al. (2008) have undertaken a comparison of BAMs versus an integrated emissions trading scheme where foreign competitors must purchase permits to import into the EU. They found BAMs were more effective in protecting domestic production and integrated emissions trading is better at reducing foreign emissions. They expressed concern about the extent to which BAMs cause emission abatement cost shifting to less energy intensive industries which may have higher abatement costs. Winchester (2011) used a CGE model to compare different BAMs with alternative firm behaviours. In a study encompassing North America, Europe, and some developing countries, Mattoo et al. (2009) examined a range of border adjustment policies in combination with environment policies. They found that border adjustments by high income countries would address most of their competiveness and environmental concerns at the expense of serious consequences for trading partners. For example, China would experience its manufacturing exports declining by one-fifth with a corresponding real income drop of 3.7 percent. Low- and middle-income countries' exports may decline by 8 percent and real income by 2.4 percent.

Burniaux et al. (2010) use the OECD's ENV-Linkages model (a dynamic global model of 12 world regions and 22 sectors) to assess the economic effects of BAMs under alternative coalitions of countries acting to cut emissions. These authors conclude that BAMs can reduce carbon leakage for small coalitions of acting countries such as the EU because when the coalition is small, the leakage occurs mainly through the short term competitiveness channel, rather than through the fossil fuel price channel. However, the need for, and effectiveness of, BAMs declines rapidly with the size of the coalition because the BAMs are addressing smaller rates of leakage. Burniaux et al. (2010) also found that the economic effects of BAMs are small. More strikingly, they found that BAMs do not necessarily curb output losses experienced by the EITEs. This is because the EITEs make significant use of (the higher cost) emissions intensive imports themselves, and also because of market contraction effects in the home country.

In a recent study, Takeda et al. (2012) isolated the effects of BAMs accompanying a carbon tax policy in Japan using a multi-regional CGE model developed using the GTAP-E database. They particularly analysed welfare decline, competitiveness loss and carbon leakage and concluded that 'no single policy is superior to the other policies' in terms of addressing simultaneously all three issues. They do note that export border adjustment is more effective in restoring the export competitiveness of Japanese industries while reducing significantly the carbon leakage. The analysis also proved that information on direct emissions (emissions from fossil fuel use) is sufficient to establishing effective border adjustment policies in Japan and indirect emissions (emissions embodied in electricity) need not be included.

Carbon motivated BAMs have been analysed in a study by Dong and Walley (2012) by developing a highly aggregated multiregional model of China, EU-27, and the US. A range of carbon prices (US$25/ton to US$200/ton) were imposed on the model to predict the impact of border adjustments. They found the regional impact of welfare, trade, and emissions of BAMs is rather small concluding that emissions intensity of different sectors matters in relative price adjustments.

Clarke and Waschik (2012) employ a static CGE model using GTAP7 data for Australia to examine the effects of a carbon tax and assess whether the scale of carbon leakages and loss of competitiveness in Australian industry sectors warrant concern. Clarke and Waschik (2012) simulate a 27% carbon emissions abatement (in order to draw comparisons with Australian Treasury modelling on the effects of a carbon tax) and this needs a carbon price of US $26.41 in the modelling. They assume Australia acts unilaterally to achieve the 27% carbon abatement and that there is no compensation to the EITEs and no BAMs.

Examining the impact of the carbon price on domestic demand, production, exports and imports in the key EITE sectors, Clarke and Waschik (2012) find small impacts and therefore no case for compensating the Australian non-metallic mineral sector (including cement) or the iron and steel sectors. They argue there is a case for protecting the Australian non-ferrous metals sector (aluminium) because of a loss of competitiveness resulting in potentially significant carbon leakage. The authors argue that in order to meet the emission abatement target, a significant increase in the carbon price is necessary when the burden of abatement falls on the unprotected sectors. This higher price itself necessitates more compensation to the protected EITEs. A key conclusion is that access to a global carbon permit market would alleviate the need to rely more heavily on unprotected industries in order to meet abatement targets. The present study extends the Clarke and Waschik (2012) study by directly simulating and analysing the effectiveness of a range of BAMs following the introduction of a carbon tax is in Australia.

3 Model Structure and Database

3.1 Model

The model used in this in the paper is the revised version of GTAP-E model (McDougal and Golub, 2007); a slightly improved version of Burniaux and Truong, 2002. This energy specific version is based on the standard GTAP model (Hertel, 1997). GTAP-E has been used in several studies of climate change policies because of its explicit treatment of substitution possibilities between energy inputs and between energy and capital in addition to its capability to incorporate CO_2 emissions (e.g. Kremers et al., 2002; Nijkamp et al., 2005; Kemfert et al., 2006; Long and Suduk, 2012).

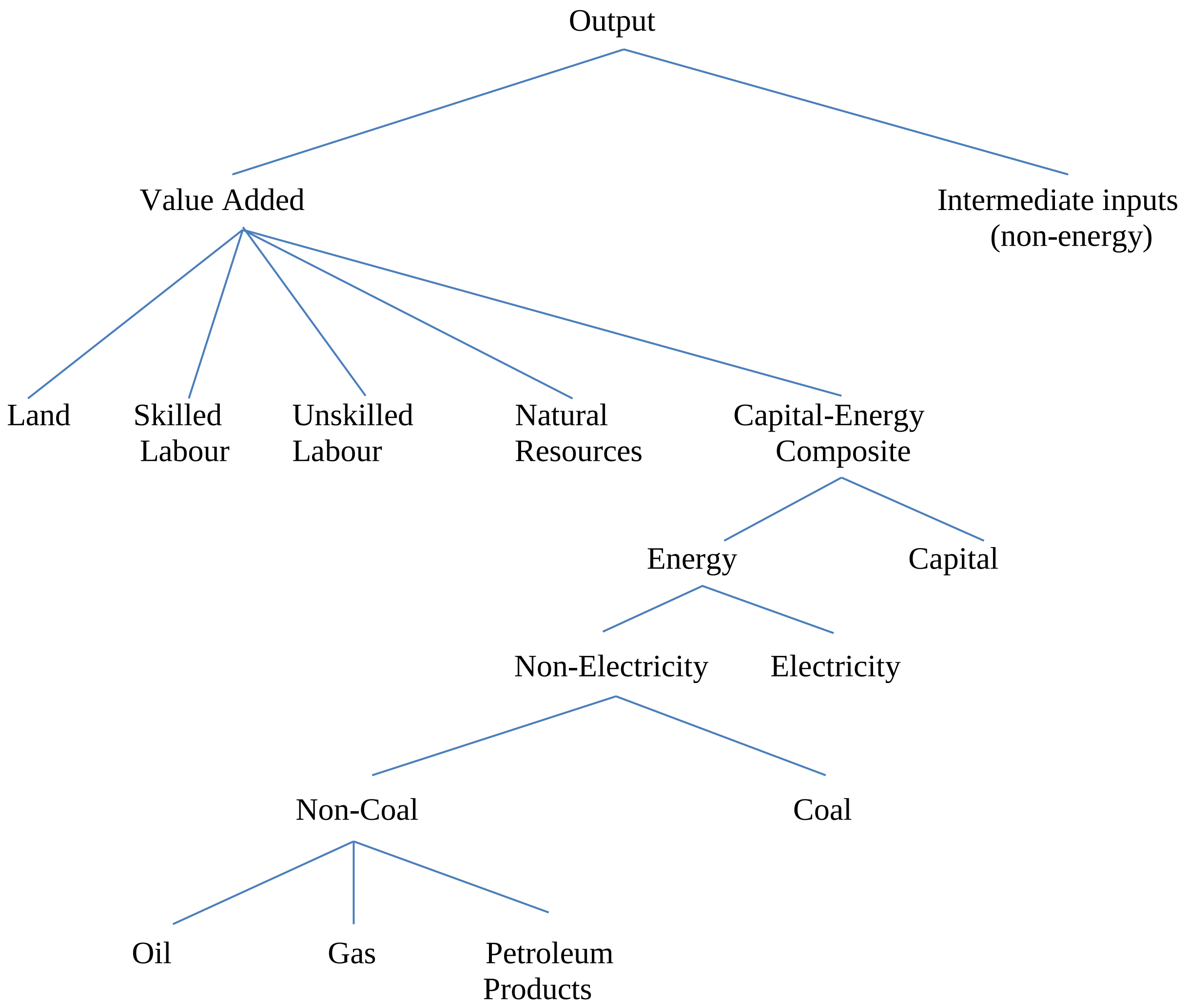
Similar to the GTAP model, GTAP-E also uses the nested Constant Elasticities (CES) of substitution production structure. This is briefly outlined in Figure 1. In the production structure there are several sub-nests and each of them allows potential for substitution between individual or composite inputs. Each composite input is a combination of commodities (inputs) at the next lower level in the tree structure as shown in Figure 1. At the top level of the production structure, firms produce outputs by combining non-energy intermediate inputs and primary factor composite or value added. The elasticity of substitution is assumed to equal zero (Leontief assumption) at this level of substitution between value added composite and non-energy intermediates. The primary factor composite is a combination of skilled labour, unskilled labour, land, natural resources, and capita-energy composite with a CES substitution between them.

Unlike in the standard GTAP specification, the production (input) structure further branches out within the capital-energy composite giving three inter-fuel substitution possibilities. They are: (i) electricity versus non-electricity composite; (ii) coal versus non-coal composite; and (iii) between oil, gas, and petroleum products. All three are modelled with CES substitution possibilities. This structure allows capturing relative price effects when one input becomes more expensive relative to the other. For example, producers can substitute away from coal for non-coal energy (a composite of oil, gas, and petroleum products), when coal becomes more expensive than non-coal energy. Similarly, if capital rental rises relative to the aggregate energy price, firms may substitute energy composite for capital.

3.2 Database and parameters

The database for the simulations is taken from GTAP-E version 8 database. It also contains most up to data emissions data disaggregated by fuel types. The base year for GTAP-E database is 2007 and we have adopted the parameter files that come with the model database without any change. Given the purpose of our analysis, we have aggregated 57 sectors in the database into 20 sectors. Similarly, 139 regions are aggregated into 12 regions, giving particular consideration to Australia's major trading partners. Table A1 in the appendix shows the sectoral and regional aggregation used in the paper.

Figure 1: Structure of Production in GTAP-E



4 Emission Intensity and Trade Exposure

The way in which carbon pricing affects international competiveness and carbon leakage is not straightforward. An important factor is the emission intensity of individual sectors when there is a price for carbon to pay. As can be seen from Table 1, there is a wide variation in emissions intensity across industries in Australia. The use of different fossil fuels directly in their production processes determines the extent of emissions intensity of individual sectors. Naturally, highly emission-intensive sectors incur significant cost increases under the carbon tax. As revealed from data in Table 1, the unique feature of Australia's CO_2 generation is that it is the electricity sector that contributes to more than 50 perecent of its total emissions with the highest emissions intensity.

Table 1 Emissions intensity and trade exposure of sectors

Symbol	Sector	Industry share in total output (%)	CO_2 (Mt)	Emissions intensity[1]	Share of exports[2] (%)	Share of imports[3] (%)	EITE sector[4]
AG-F-F	Agriculture, forestry & fishing	4.28	5.66	0.36	9.51	1.83	N
COAL	Coal	1.11	2.50	0.34	90.14	0.00	Y
OIL	Crude Oil	0.61	1.41	0.48	33.09	71.56	Y
GAS	Natural gas	0.52	3.41	1.63	51.60	7.93	Y
OMN	Other minerals	2.71	7.64	0.36	58.61	1.78	Y
FOOD	Food	3.70	3.11	0.07	24.20	11.47	N
TEX	Textile & leather	0.59	0.41	0.06	14.64	78.81	N
WPP	Wood, paper products	2.07	1.87	0.09	7.54	19.98	N
OIL-P	Oil products	1.49	12.56	0.53	8.27	31.33	Y
CRP	Chemical, rubber, plastics	1.98	4.46	0.19	21.16	59.97	Y
NMM	Mineral products	0.78	6.45	0.77	2.63	14.87	Y
I-S	Ferrous metals	0.98	2.80	0.23	17.90	17.68	Y
NFM	Metals nec	2.17	13.50	0.44	83.08	14.82	Y
FMP	Metal products	1.17	0.16	0.01	4.72	19.34	Y
MVN	Motor vehicles & parts	3.28	0.17	0.01	23.32	107.36	N
ELE	Electronic equipment	0.38	0.03	0.01	18.00	222.69	N
OMF	Other manufacturing	0.53	0.00	0.00	13.09	40.61	N
ELY	Electricity	0.38	212.05	14.33	0.00	0.00	N
TRP	Transport services	7.20	63.20	0.86	9.18	10.14	N
SER	Other services	62.95	5.60	0.01	2.17	1.81	N

Notes:

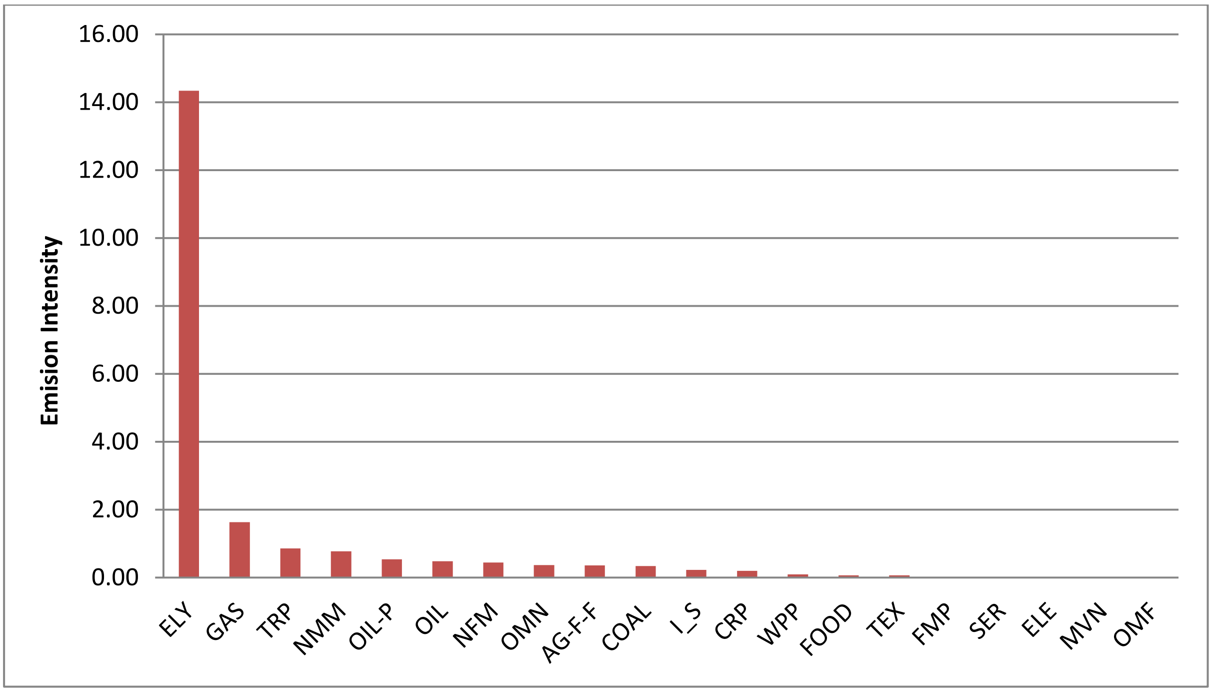
1. Emissions intensity is defined as emissions (tCO_2) per 1000US$ of output.
2. Export as a share of the total output of a sector.
3. Imports as a share of the total output of a sector.
4. N=No; Y=Yes.

Source: GTAP-E Version 8 database.

Figure 2 depicts the emissions intensity (tCO_2 per US$1000 output) by sector in the Australian economy. Not surprisingly, the electricity generating sector (ELY) is the most emission intensive activity in Australia according to Figure 1. In addition, some of the energy production sectors (GAS, NMM, OIL, OIL-P, OMN, and COAL), manufacturing sectors (I_S and CRP) and agriculture (AG-F-F) are high in carbon emissions. The transport sector (TRP) also records sizable emission intensity in Australia. These are the sectors that will be affected significantly under carbon pricing.

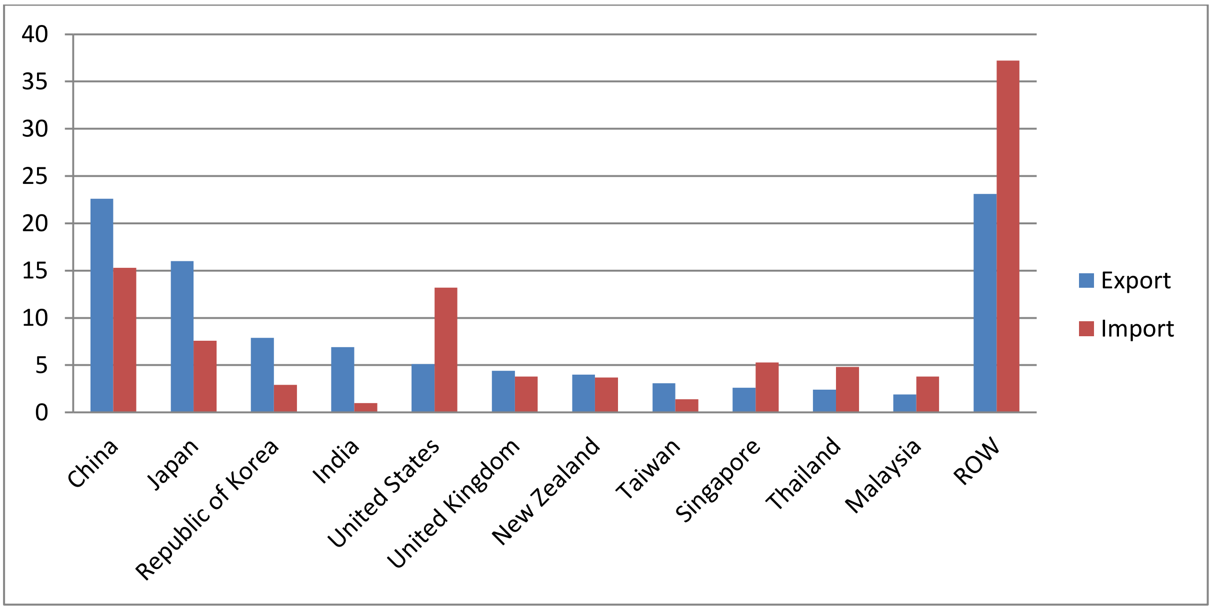
Figure 3 shows the export and import shares of Australia according to the destination and source respectively. Among Australia's eleven major trading partners, Japan, United States,

Figure 2 Carbon Emissions Intensity by Sector in Australia (tCO_2/US$1000)



Source: Calculated from GTAP database version 8.

Figure 3 Export and Import Shares of Australian Trade(%)

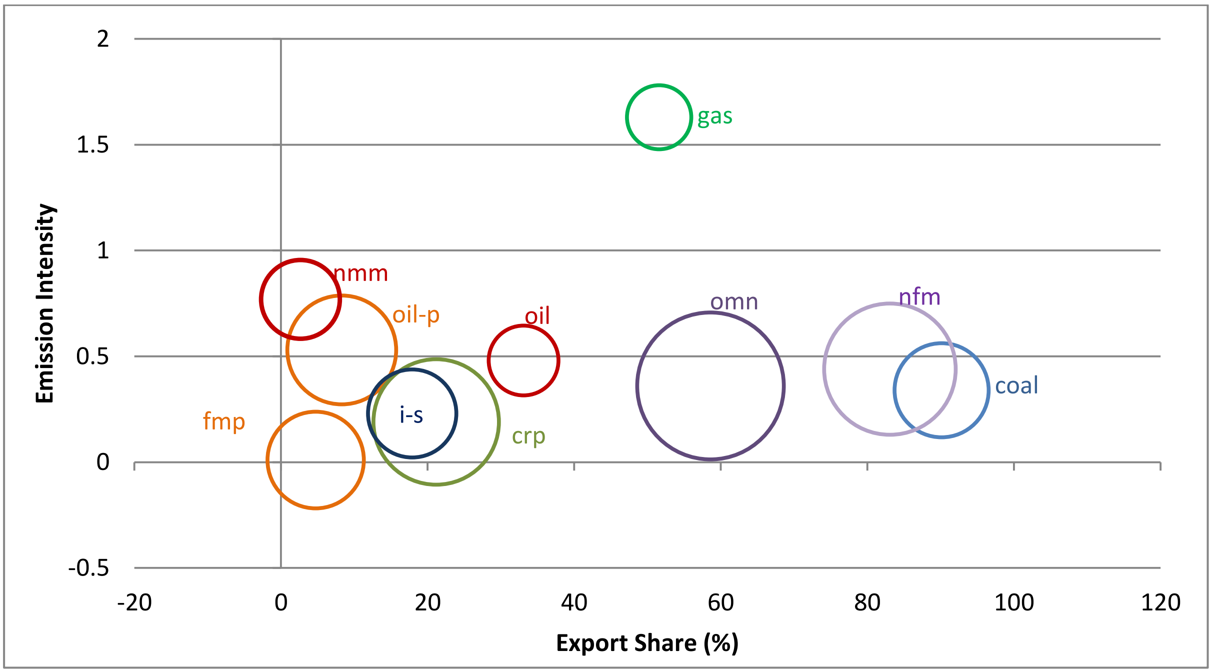


Source: Calculated from data obtained from the Department of Foreign Affairs and Trade (DFAT).

United Kingdom and New Zealand belong to Annex 1 countries of the Kyoto Protocol having obligations to reduce emissions. However, Australia's primary Asian trading partners including China, South Korea, India and the rest of Asia are not obliged to cut emissions.

This would imply that the Australian carbon tax to regulate emissions may hurt the competitiveness of EITE sectors in Australia relative to those in China, South Korea, India and rest of Asia.

Figure 4 Emissions Intensity and Export Exposure of Sectors



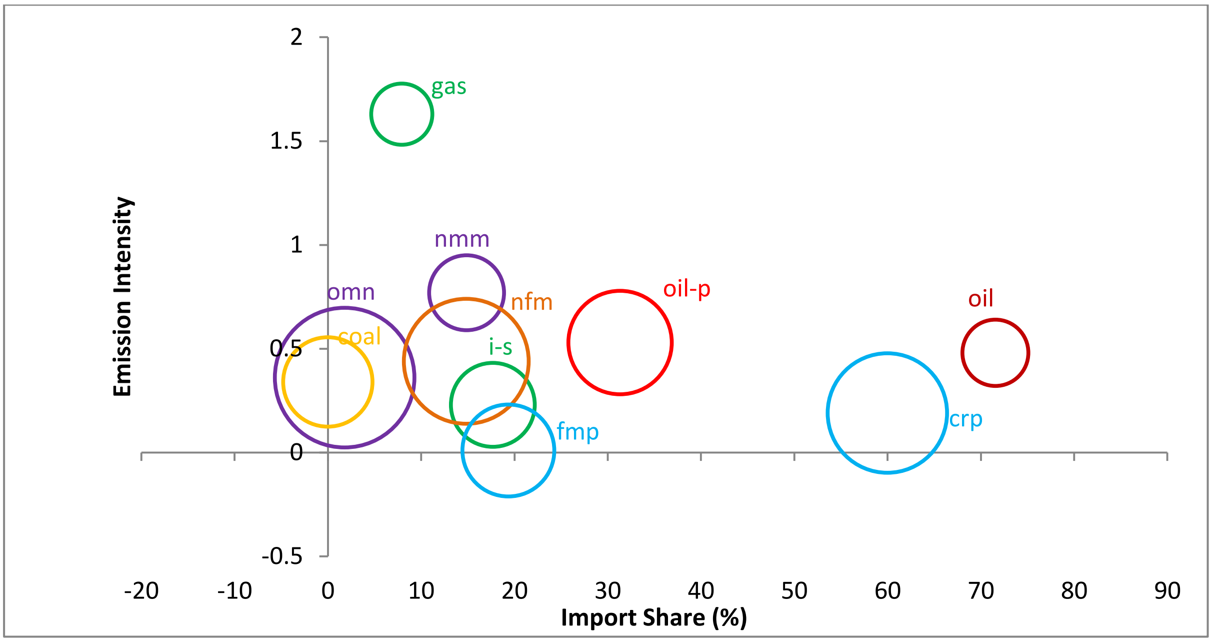
Note: Size of bubble represents the share of outputs in the economy of particular sectors.

Source: Calculated from GTAP-E version 8 database.

Figure 4 displays three dimensions which are important determinants of relative competitiveness of individual sectors under climate policy: emission intensity, export exposure and output share. Using data from Table 1, we have selected 10 sectors as EITE sectors and that are likely to be affected by the cost increases under the carbon tax policy, depending on their respective emissions intensity. The size of the 'bubble' represents the share of output in the economy by a given sector. In fact it is an indication of the relative significance of the sector in the economy. As can be seen from the figure, there is a wide range of variability in the three dimensions while many sectors cluster towards the horizontal axis of the diagram implying low to moderate emissions intensity with high trade (export) exposure.

A similar observation can be made from Figure 5 where emissions intensity, import exposure and the size of output are displayed simultaneously. They are the same 10 EITE sectors and some of them may face import competition and may have been disadvantaged under the policy of domestic emissions control. A majority of these import competing sectors experience low to moderate emissions intensity accompanied by high import penetration. These imports are primarily sourced from countries which are not under obligation to cut emissions.

Figure 5 Emissions Intensity and Import Exposure



Note: Size of bubble represents the share of outputs in the economy of particular sectors.

Source: Calculated from GTAP-E version 8 database.

5 Carbon Tax and Border Adjustment

This section describes the basis of the GTAP-E model simulations to examine the impact of different BAMs. The Australian government has implemented the carbon tax at the rate of A$23 per tonne of CO2-equivalent with the exemption of agriculture, road transport and household sectors. We have used this carbon tax rate in each simulation scenario. The government has proposed a number of compensation plans outlining the ways the revenue collected through the tax will be used. They include compensation to selected manufacturers and exporters, reform of income tax thresholds, and family tax benefits such as a clean energy advance, clean energy supplement, and single income family supplement. These measures are quite complex and it is hard to capture them all in a single model. In the model simulations we adopt a modest and simplified compensation plan. We use in each scenario a revenue-neutral straightforward household compensation plan: that is, it is assumed that we provide a subsidy to the representative household to maintain their pre-tax aggregate consumption level.

Table 2 Border Adjustment Scenarios

Scenario	BA for exports	BA for imports	BA for production
NBA	None	None	None
BAE	All sectors	None	None
BAI	None	All sectors	None
BAP	None	None	All sectors
BAEI	All sectors	All sectors	None

In general, BAMs are used to compensate countries where environmental taxes are levied. For example, exporting countries may give a rebate (subsidy) to exporters to relieve them from increased cost due to a carbon tax, which would otherwise make them uncompetitive in global markets, and importing countries may impose carbon tariffs (green tariffs) equivalent to what would have been charged had the products been produced domestically. The export rebate and carbon tariffs are to be determined according to the carbon content of exports and imports to maintain a levelled playing field and to ensure the effectiveness of border adjustment policies.

We have adopted four border adjustment scenarios as summarised in Table 2. No border adjustment (NBA) scenario is the base simulation where $23 carbon tax is imposed. The BAE scenario involves providing an export rebate when the carbon tax is in place, whereas BAI introduces a carbon tariff on imports. In addition, we can use a policy to mitigate the impact of carbon regulation on domestic costs of production by giving rebates to all domestic producers, not only exporters. In Table 2, BAP refers to this border adjustment policy. The final measure, BAEI, is the full border adjustment where both export rebate and carbon tariffs are applied to both exports and imports simultaneously to mitigate the domestic impact of carbon tax.

For the purposes of this study, all BAMs have been based on the direct emissions (on-site fuel emissions) plus our separate calculations of indirect emissions (emissions embodied in energy inputs, e.g., the use of electricity generated off-site). Following Takeda et al. (2012), we let q_{jr}^{CO2T} to be the total amount of CO_2 generated by the j^{th} sector in a given region r. Then we define q_{jr}^{CO2T} to include both direct and indirect emissions. That is:

$$q_{jr}^{CO2T} = q_{jr}^{CO2D} + q_{jr}^{CO2ID}$$

where q_{jr}^{CO2D} and q_{jr}^{CO2ID} are the direct and indirect CO_2 emissions by the j^{th} sector in region r, respectively. By definition, direct emissions of CO_2 are obtained via:

$$q_{jr}^{CO2D} = \sum \phi_{ejr} q_{ejr}$$

where ϕ_{ejr} is the emissions coefficient of fossil fuel e in sector j of region r and q_{ejr} is the amount of fossil fuel used by sector j in region r.

In order to estimate the indirect emissions in our study, we first define θ_{jr}^{ELE} as the share of electricity used in sector j in region r via:

$$\theta_{jr}^{ELY} = d_{jr}^{ELY} / q_{ELY,r}$$

where d_{jr}^{ELY} is the amount of electricity used by sector j in region r and $q_{ELY,r}$ is total supply of electricity in region r. We also define the total direct emissions of CO_2 by the electricity sector in region r as $q_{ELY,r}^{CO2D}$ and then calculate the indirect emissions attributed to each sector j in region r from the formula:

$$q_{jr}^{CO2ID} = \theta_{jr}^{ELY} \; q_{ELY,r}^{CO2D} \; .$$

Finally, CO_2 emissions per unit of output (emission intensity) in sector j in region r, (δ_{jr}), are obtained as:

$$\delta_{jr} = q_{jr}^{CO2T} / q_{jr}$$

where q_{jr} is the total value of output (US$ value) of sector j in region r. Note that δ_{jr} represents both direct and indirect emissions per unit of output.

The carbon tariff (or subsidy) assigned to each sector (commodity) based on the emission intensity is then defined by:

$$\pi_{jr} = p^{CO2} \delta_{jr}$$

where p^{CO2} is the price of carbon per tonne of CO_2. In scenario BAI, an import tariff of π_{jr} is imposed on all imports; in scenario BAE, a subsidy of π_{jr} is used for each exportable good. In the case of scenario BAP, a subsidy of π_{jr} could be given to each sector. As the scope of the subsidy is much wider (all producers instead of all exporters) in this scenario, this policy would cause much larger government spending. For comparison purposes, the shocks of the production subsidies applying to all producers are scaled down so that the total production subsidy in this scenario equals the total subsidy to exporters in scenario BAE.

As our concern is the long-run impact of border adjustments, we have used the long-run closure of the GTAP-E model in all simulations. The key underlying features of the closure include fixed real rentals and skilled and unskilled labour, free movement of capital and flexible real wages.

6 Simulation Results

This section compares the results of the BAMs (BAE, BAI, BAP and BAEI) simulations with the no border adjustments (NBA) option when the carbon tax is in place at $23 (equal to 18.5 US$) per tonne. The general presumption is that the policy of carbon control with the tax will hurt EITE sectors in the Australian economy hence some measures of compensation are needed to ensure a levelled playing field with their overseas competitors. Using the GTAP-E model, we examine the economic and environmental effects of BAMs. Particularly, we focus on changes in Australia's GDP and welfare levels, aggregate trade outcomes, domestic emissions reductions, and sectoral outputs, exports, and imports.

6.1 Macroeconomic and Trade Impact of BAMs

The results from border adjustment policy simulations are reported in Table 3 for key macroeconomic variables, and trade aggregates. It is not surprising to see that carbon pricing lowers Australia's real GDP by 1.4 percent in the NBA scenario. The emission controlling new tax distorts resource allocation to some degree causing inefficiency. Facing an increase in production costs, the industries will respond to the tax by reducing outputs which has a direct negative impact on Australia's real GDP. The projected welfare loss due to the carbon tax measured in terms of the equivalent variation (EV) is approximately US$M 8,179. These consequences may partly be attributed to losing competitiveness due to the environment tax to reduce domestic emissions without a global agreement.

The impact of the four BAMs on real GDP and welfare are shown in the second and third rows of Table 3. How does each border adjustment policy fare in the economy is an interesting question. As Australian industries are compensated for their loss in competitiveness through these measures, one should expect some improvement according to the economic analysis of border adjustments. It appears that the domestic production rebate (BAP) and export border adjustment (BAE) have a modest cushioning effect (i.e. GDP reduction is marginally less than in NBA). Interestingly, however, there seems to be no

Table 3 Key Macroeconomic and Trade Results from the Simulations

	NBA	BAE	BAI	BAP	BAEI
Carbon tax (A$/t$CO_2$)[a]	23	23	23	23	23
Real GDP	-1.40	-1.39	-1.40	-1.37	-1.39
Welfare (EV) (US$m.)[b]	-8179.6	-8688.8	-8722.0	-8516.4	-8691.1
Export volume	-1.70	-1.68	-1.71	-1.67	-1.69
Import volume	-2.58	-2.55	-2.59	-2.52	-2.56
Export price	0.17	0.17	0.17	0.17	0.17
Import price	0.02	0.02	0.02	0.02	0.02
Terms of trade	0.16	0.15	0.16	0.16	0.16
Balance of trade (US$ m.)[b]	1884.3	1871.7	1885.8	1827.6	1873.3
Carbon leakage rate	7.22	7.23	7.22	7.28	7.23

Source: Model simulations.
Note: (a) This is equivalent to US$18.5 after adjusting for the exchange rate between A$ and US$ in 2007. (b) All projections are in percentage changes from the base period except the equivalent variation (EV) and the balance of trade.

discernible benefit to the economy by using import border adjustment or green tariffs (BAI). The simultaneous use of BAE and BAI (the BAEI scenario) does not improve the outcome beyond what BAE does. The deadweight losses arising from the distortionary rebates (subsidies) and tax (green tariffs) are responsible for the deeper welfare losses experienced under BAMs. Among the four border adjustment policies, green tariffs appear to be more severely affecting the welfare level because it has an inflationary impact on the broader economy.

We next consider what happens to trade aggregates when BAMs are in place to support the EITE sectors in the economy. The policy of export rebate (BAE) is targeted to assisting exporters where the additional costs of production incurred due to the carbon pricing policy are rebated when goods are exported from Australia. Our projections show that the reduction in export volume is lowered by using BAE and BAP to some degree, but again, it is interesting to note that the adoption of green tariffs in Australia is likely to further deteriorate exports as shown by a slightly higher 1.71 percent reduction in the export volume compared to the NBA outcome (-1.70 percent). The imposition of tariffs makes inputs to export producers more expensive. Hence there is a squeeze in the profit margins in the absence of their ability to pass on the increased costs to customers. As can be seen from Table 3, carbon regulation causes a rise in export prices and BAMs have no impact towards easing them.

Similarly, all BAMs tend to cause no change in import prices beyond what has been experienced under the carbon price. These import and export price movements imply almost no change in the terms of trade by using different border adjustment strategies in Australia. There is a large balance of trade surplus under carbon tax that is generated by the positive terms of trade impact. Export and production rebates affect the balance of trade surplus slightly by reducing its size. However the green tariffs have almost no impact on the balance of trade.

We now turn to the leakage rates under different scenarios. Critics of emission control strategies by a carbon pricing policy have argued that the end result of the policy would be that domestic import competing sectors lose competitive advantage, adding to carbon leakage. Our findings (see Table 3) do not support this argument as they indicate that the leakage rate is considerably low (7.22 percent) in the Australian case as a consequence of adopting the carbon tax. As seen from Figure 2, Australia's major sources of imports include many Asian countries (China, South Korea, India, Taiwan, Singapore, Thailand, and Malaysia) which do not have commitments to reduce emissions. Hence the increased demand for imports by Australia from these sources was thought to be contributing to carbon leakage under a unilateral carbon tax. Results from GTAP-E simulations prove that the contribution to carbon leakage through this trade channel is over exaggerated by the opponents to carbon pricing in Australia. China seems to experience slightly increased emissions (little over 1 $MtCO_2$) compared to other trading partners after Australia adopting the carbon tax policy but rest of Australia's major trading partners have very small increases in CO_2, less than 1 $MtCO_2$ per each country (region). Adding all up, there are about 9 more $MtCO_2$ emitted globally after Australia introducing the policy, according to GTAP-E simulations.

Table 3 reports leakage rates under each BAM. The introduction of BAMs in Australia has very little impact on the leakage rates. In other words, trade measures such as export rebate and green tariffs do not suppress the level of global emissions from the position of NBA outcome. Production rebates tend to increase the leakage rate slightly (from 7.22 to 7.28) because the policy tends to draw more imports from overseas.

6.2 Environmental Impacts

The simulated environmental impacts of BAMs are compared with the base simulation (NBA) in Table 4. According to GTAP-E projections, the introduction of the carbon tax is effective as it reduces Australia's emissions by about 81 $MtCO_2$. Given Australia's aggregate emissions base of 381 $MtCO_2$ in 2007 from fossil fuel uses, this gives a 21.34 percent reduction rate.

Table 4 Selected Projections on Environmental Variables

	NBA	BAE	BAI	BAP	BAEI
Carbon tax (A$/$tCO_2$)	23	23	23	23	23
Percentage reduction of emissions	-21.34	-21.32	-21.34	-21.17	-21.32
Aggregate reduction of carbon emissions (Mt)	-81.37	-81.29	-81.37	-80.72	-81.29
Carbon tax revenue (US$ billions)	5.55	5.55	5.55	5.56	5.55
Carbon tax revenue (A$ billions)	6.89	6.90	6.89	6.91	6.90

Source: GTAP-E model simulations.

A closer observation of the impact of BAMs on emission reduction reveals that export and production rebates work against the environmental objectives of the carbon pricing, even though the effect is mildy. That is both of these policies tend to discount Australia's effort to cut emissions compared to the base case scenario (NBA). While these two measures may be appealing for reducing potential carbon leakage and mitigating the loss of competitiveness, they do tend to undermine Australia's effort to reducing its own emissions. Nevertheless the modest increase in carbon tax revenue due to using such measures to assist domestic industries may provide a slight conciliation to their proponents. The carbon tax generates about A$ 6.89 billion (US$ 5.55 billions) and the revenue fluctuates only marginal under the influence of all BAMs.

6.3 Impact on Competitiveness of EITE sectors

In this section we examine the impact of BAMs on competitiveness of sectors using changes in sectoral outputs, exports and imports. The adjustments to the economy are based on carbon emissions of sectors (emission intensity) in the border adjustments framework and therefore relative price movements play a key role in the sectoral behaviour in response to the policy.

In panel one of Table 5 displays the changes in export volumes by EITE sectors under the policy of carbon tax and their response to border adjustments. The first thing to notice is most of the export intensive EITE sectors experience a significant increase in export volumes when emissions are controlled with the tax (NBA scenario). These sectors are: Coal (COAL), Crude oil (OIL), Natural gas (GAS), and Other minerals (OMN). As carbon pricing is introduced, these sectors experience reductions in domestic demands but foreign demand rises as these energy goods are becoming relatively cheaper to foreign customers. Unilateral domestic policy to control emissions tends to reduce domestic consumption of energy intensive goods putting a downward pressure on prices for such goods at the global level. The carbon pricing has also increased exports in Metal products (FMP) and Chemical, rubber and plastics (CRP) sectors. Four IETE sectors – Oil products (OIL-P), Mineral products (NMM), Ferrous metals (I-S), and Metals nec (NFM) – are projected to lose their export sales under carbon tax. These sectors are truly affected by the cost increases and hence face reduced competitiveness in overseas markets.

The application of BAMs affects exports of different sectors by small margins according to our findings. The export rebate improves the performance of most of the sectors but very slightly. The NFM sector appears to be the highest gainer from the policy. The green tariffs (BAI) make exports from EITE sectors even lower than in NBA. The competiveness of exportable goods deteriorates as a result of imposing green tariffs on imports. This is attributed to additional costs experienced by exporting industries due to the import tax. The production rebate (BAP) makes some sectoral exports to be higher marginally than the NBA outcome and the I-S and NFM sectors appear to be doing better than others according to the model projections.

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Table 5 Impact of Border Adjustments on Exports, Imports and Outputs of EITE Sectors

Sector	NBA	BAE	BAI	BAP	BAEI
Exports:					
Coal (COAL)	0.61	0.64	0.61	0.61	0.63
Crude Oil (OIL)	9.77	9.74	9.74	9.74	9.71
Natural gas (GAS)	8.21	8.45	8.17	8.17	8.42
Other minerals (OMN)	0.61	0.61	0.61	0.61	0.61
Oil products (OIL-P)	-2.79	-2.78	-2.81	-2.81	-2.81
Chem., rub., plas. (CRP)	0.41	0.39	0.39	0.39	0.37
Mineral products (NMM)	-4.44	-4.38	-4.45	-4.45	-4.39
Ferrous metals (I-S)	-4.06	-4.04	-4.08	-4.08	-4.06
Metals nec (NFM)	-16.93	-16.76	-16.95	-16.95	-16.78
Metal products (FMP)	2.25	2.17	2.22	2.22	2.14
Imports:					
Coal (COAL)	-26.82	-26.78	-26.86	-26.86	-26.81
Crude Oil (OIL)	-8.75	-8.69	-8.78	-8.78	-8.73
Natural gas (GAS)	-3.00	-2.86	-3.18	-3.18	-3.04
Other minerals (OMN)	-14.47	-14.34	-14.49	-14.49	-14.36
Oil products (OIL-P)	-7.19	-7.17	-7.21	-7.21	-7.18
Chem., rub., plas. (CRP)	-1.55	-1.53	-1.56	-1.56	-1.54
Mineral products (NMM)	0.79	0.83	0.74	0.74	0.77
Ferrous metals (I-S)	0.56	0.58	0.52	0.52	0.54
Metals nec (NFM)	1.76	1.80	1.67	1.67	1.71
Metal products (FMP)	-2.46	-2.42	-2.45	-2.45	-2.41
Outputs:					
Coal (COAL)	-7.02	-7.00	-7.03	-7.03	-7.00
Crude Oil (OIL)	-0.49	-0.51	-0.48	-0.48	-0.51
Natural gas (GAS)	-4.53	-4.41	-4.53	-4.53	-4.41
Other minerals (OMN)	-5.29	-5.24	-5.29	-5.29	-5.25
Oil products (OIL-P)	-6.18	-6.17	-6.18	-6.18	-6.17
Chem., rub., plas. (CRP)	-0.87	-0.89	-0.87	-0.87	-0.89
Mineral products (NMM)	-1.88	-1.88	-1.87	-1.87	-1.87
Ferrous metals (I-S)	-2.07	-2.08	-2.07	-2.07	-2.08
Metals nec (NFM)	-15.68	-15.54	-15.69	-15.69	-15.55
Metal products (FMP)	-1.08	-1.09	-1.09	-1.09	-1.10

Source: GTAP-E model simulations.

Table 5 depicts the change in import volumes under different BAMs in comparison to NBA. Sectors that are facing significant cost increases under the carbon tax tend to import more. This is the experience of NMM, I-S, and NFM sectors. The rest of the sectors reduce imports significantly when the carbon tax is in place. In general, export rebate (BAE) increases imports across the board whereas green tariffs (BAI) reduce imports very slightly in all the sectors. Although marginal, this is the desired effect because imports are becoming less competitive in the domestic market when border protections are imposed, than in NBA case. However the production rebate (BAP) tends to increase imports in most of the EITE sectors.

The change in outputs of EITE sectors of the Australian economy under a carbon tax are compared with outcomes of BAMs in the third panel of Table 5. Under NBA, output declines in all the sectors due to the import competition, declining domestic demand and decreases in exports, showing a wide range of deviation across sectors. The highest reduction in output is projected to be in Metals nec (NFM) sector. The aluminium production is a significant activity in this sector and it uses electricity as one of the main inputs. The rise in the price of electricity has hit hard this sector's profitability leading to its output fall. In addition, there appears to be a significant competition from imports to this sector. This large decline in output in NFM is followed by Coal (COAL), Oil Products (OIL-P), Other minerals (OMN), Natural gas (GAS), and Ferrous metals (I-S). As noted before, a border adjustment policy of green tariffs (BAI) has no alleviating effects on the decline in exports and may even cause exports to decrease further. On the other hand export and production rebates ease the decrease in exports to some degree, making output reductions slightly smaller than in NBA.

7 Conclusions

In this paper we have analysed possible carbon motivated border adjustment policies in Australia using the GTAP-E model. The model was first simulated under a $23 carbon tax to produce the benchmark solution (NBA). Then we introduced four BAMs to compare with the NBA scenario to examine how such measures could affect macroeconomic, welfare and trade outcomes. With these projections, the analysis was then directed to assessing the key issues of competitiveness and carbon leakage in relation to the performance of the EITE sectors in the Australian economy. The most important finding from our analysis is that the Australian carbon tax contributes to a relatively small carbon leakage. It is also clear that border adjustment policies have a very small impact on the overall economy and on EITE sectors. In other words, the different BAMs that we have considered are unlikely to change the outcomes of carbon pricing policy in Australia in any significant way. This finding is consistent with studies for EU, US, Canada and other countries.

Among the four policies analysed, production and export rebates are somewhat appealing even though their effects towards easing the negative impact on EITE sectors are fairly small. The green tariffs do not appear to be playing any significant role to alleviate the import competition in the domestic economy and thus have no discernible influence on reducing carbon leakage. They do, in fact, cause Australia's exports to decrease further due to a cost-price squeeze. Full border adjustment with green tariffs and export rebates is unlikely to change the outcomes beyond what export rebates may achieve alone.

As analysed in the results section, BAMs do produce slight GDP improvements (except in the BAI scenario). However this improvement comes at the expense of the emissions reduction effects of carbon pricing. When border adjustments reduce the overall emissions reduction rate, carbon tax revenue to the government becomes slightly higher.

The smallness of numerical findings confirm that BAMs would be unimportant as part of environmental policy in Australia even though critics of the carbon pricing policy, along with industry lobby groups, pressured the Australian government to introduce such measures to support EITE sectors in the economy. Hence a key policy implication of the analysis presented in this paper is that border adjustments are not warranted in the Australian case to safeguard EITE industries. They make no significant difference to Australia's commitment to a low carbon economy.

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Appendix

Table A1: Regional and Commodity Aggregation

Aggregated Region	GTAP Region	Aggregated Commodity	GTAP Commodity
1.Australia (AUS)	Australia	1.Agriculture, forestry & fishing (AG-F-F)	Paddy rice; wheat; cereal grains nec; vegetables, fruit, nuts; oil seeds; sugar cane, sugar beet; plat-based fibers; crops nec; bovine cattle; sheep and goats, horses; animal products nec; raw milk; wool silk-warm cocoons; forestry; fishing
2.China (CHIN)	China		
3.Japan (JPN)	Japan		
4.United States (USA)	United States		
5.Korea ((KOR)	Korea		
6.Singapore (SGP)	Singapore		
7.United Kingdom (GRB)	United Kingdom		
8.New Zealand (NZL)	New Zealand		
9.India (IND)	India		
10.Thailand (THA)	Thailand		
11.Malaysia (MYS)	Malaysia	2.Coal (COAL)	Coal
12.Rest of World (ROW)	All other regions	3.Crude oil (OIL)	Oil
		4.Natural gas (GAS)	Gas; gas manufacture and distribution
		5.Other minerals (OMN)	Minerals nec
		6.Food (FOOD)	Bovine cattle, sheep and goat meat products; meat products; vegetable oils and fats; dairy products; processed rice; sugar; other food products nec; beverages and tobacco products
		7.Textile & leather (TEX)	Textiles; wearing apparels; leather products
		8.Wood, paper products (WPP)	Wood products; paper products, publishing
		9.Oil products (OIL-P)	Petroleum, coal products
		10.Chemical, rubber, plastic (CRP)	Chemical, rubber, plastic products
		11.Mineral products (NMM)	Mineral products nec
		12.Ferrous metals (I-S)	Ferrous metals
		13.Metals nec (NFM)	Metals nec
		14.Metal products (FMP)	Metal products
		15.Motor vehicles & parts (MVN)	Machinery and equipment nec
		16.Electronic equipment (ELE)	Electronic equipment
		17.Other manufacturing (OMF)	Manufactures nec
		18.Electricity (ELY)	Electricity
		19.Transport services (TRP)	Transport nec; water transport; air transport
		20.Other services (SER)	Water; Construction; trade; financial services nec; insurance; business nec; recreational and other services; public admin., defence, education, health; ownership of dwellings

Source: GTAP-E version 8 database.