Australia in an International Emissions Trading (ETS) Scheme: An Economic Evaluation Using the GTAP-E Model*

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Abstract:

We use the GTAP-E model to analyse two emissions trading scheme (ETS) scenarios under the cap-and-trade system at global level, building on pledges for abatement made by governments after the Copenhagen Accord (2009) and Cancun Agreement (2010). These pledges are used to allocate emissions targets for all the countries in 2020. In the first scenario, an ETS is formulated among Annex 1 countries only. In the second scenario, the ETS is expanded by adding three leading non-Annex 1 emitters – China, India and South Korea. The study shows that the cost of meeting emissions reduction commitments of Australia and other countries can be reduced by engaging in block-level emissions trading. According to the results, a permit price (price per tonne of $CO_{2\text{-}e}$) of US$10.56 emerges with the ETS among Annex 1 countries. This price is reduced to US$6.32 when China, India and South Korea also joined the global ETS. Australia's real GDP declines by 1.03 and 0.59 percent respectively in two ETS scenarios. Contrary to the widely held view, projections from the GTAP-E model suggest that the ETS has a modest overall economic impact on the Australian economy and globally. Our results confirm that selling permits to the world is not welfare enhancing; rather countries who buy permits improve their welfare.

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1. Introduction

In the absence of a global agreement on climate change policies, Australia's short-term climate target is to reduce greenhouse gas (GHG) emissions by 5 per cent below the 2000 level by 2020. Australia may increase its target to 15 or 25 percent if an integrated international emissions reduction goal is set in the future under the auspices of UNFCCC. The current Australian target of GHG has received bi-partisan support even though two major political parties hold diverging views with regard to the policy choices to combat the issue of human-induced climate change. The former federal Labor government which favoured the market driven approach to climate policy introduced the carbon tax as the centrepiece of its Carbon Pollution Reduction Scheme (CPRS) to achieve Australia's abatement obligation under the Kyoto Protocol. The Coalition elected to government at the 2013 Australian federal election repealed the carbon tax from 1st July 2014 and decided to retain the compensating social security increases and income tax rate reductions introduced by Labor under its carbon price legislation. The Coalition's new climate policy that has replaced the carbon price is a general subsidy scheme known as Direct Action that comes into operation from July 2015 (Australian Government, 2014). The central to this policy is the Emissions Reduction Fund (ERF) which is designed to handle the proposed subsidy scheme.

The efficacy of ERF to reduce emissions in Australia to meet its abatement commitments has been a subject of ongoing debate. Critics argue that the policy may not achieve its goals as the budgetary allocation to implement the ERF is well short of its need to meet Australia's abatement target (Clarke et al., 2014). Furthermore, there is a speculation that the forthcoming UN Framework Convention for Climate Change (UNFCCC) summit in 2015 may come to a firmly committed global agreement on emissions reduction targets. Such a global agreement on abatement may put extra pressure on Australia to explore cost-effective means to reduce emissions. Given the uncertainties of the Direct Action plan and its central machinery of ERF to achieve Australia's emissions reduction target, it is worth considering market based alternatives such as an emissions trading scheme (ETS) encompassing both domestic and international carbon markets. In December 2014, the present Minister for the Environment has requested the Climate Change Authority (CCA) to undertake an inquiry into whether Australia should have an ETS in the future[1]. The primary advantage of such a

[1] The Minister's directives to CCA further include that its investigation should take into account the nature and stance of climate policies of other countries such as USA, China, Japan, South Korea, and the European Union.

scheme compared to other policy options would be its market-based approach and potential to minimise the costs of achieving a given level of GHG reduction target. Further, a national emissions trading scheme could readily be integrated into an international trading system such as the EU-ETS, Annex 1-ETS or an Asian-ETS; emissions credits earned offshore by companies and other entities through the Kyoto Protocol mechanism could be included in such a scheme.

This paper analyses the impact of two potential international emissions trading schemes in which Australia is one of the trading partners and both schemes operate under a cap-and-trade system to meet the 2020 target emissions. The primary aim of the study is to investigate the macro and sectoral effects of emissions trading in an international setting and the potential implications for domestic carbon regulation in Australia. We propose two ETS scenarios using the cap-and-trade system at global level, building on pledges made by governments after the Copenhagen Accord (2009) and Cancun Agreement (2010). These pledges are used to allocate emissions targets for all the countries in 2020. In the first scenario, an ETS is formulated with Annex 1 countries only while three major non-Annex 1 countries, China, India and South Korea, undertake domestic emissions trading schemes of their own. In the second scenario, the proposed ETS is expanded by adding three leading non-Annex 1 emitters – China, India and South Korea- to the international ETS. The study shows that the cost of meeting emissions reduction commitments of Australia and other countries can be reduced by engaging in block-level emissions trading. The analysis is undertaken with the GTAP-E model which has a detailed specification of energy substitution possibilities, sectoral and regional disaggregation, and carbon emissions accounting. The results reported in the paper are based on GTAP-E version 8.1 database. We have updated the emissions database of the model by incorporating non-CO_2 emissions data published by the GTAP group. To accommodate these changes in the database, we have modified the GTAP-E model as well. This revision has enabled us to use $CO_{2\text{-}e}$ rather than CO_2 in our modelling.

The paper is organised as follows. A brief survey of literature is presented in Section 2 to position the present contribution in the context of earlier research on emissions trading. Section 3 is an overview of the modelling framework and the scenario design. In Section 4, we analyse the simulation results. Section 5 concludes the paper.

2. Economics of Emissions Trading – Survey of Literature

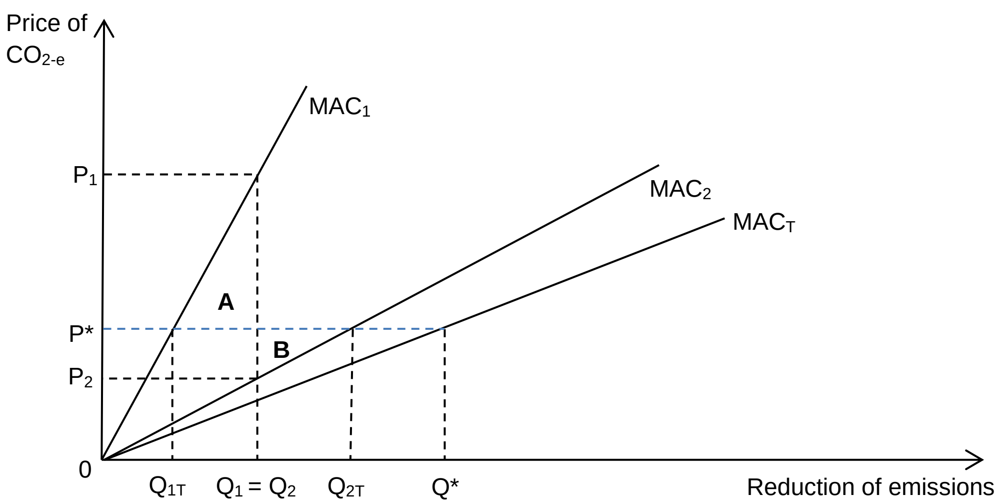
An externality generated by one agent can affect other agents' welfare when that externality is not reflected in the market price. Hence producers of externalities are not normally obliged to take into consideration the effects of their decisions on others. GHG emissions are regarded as a negative externality. A divergence between private and social costs is caused by a negative externality. Usually in the presence of externalities such as GHG, the private cost of polluting activities is an under-estimation of the true social cost simply because it ignores the external cost of damage generated by pollution. The resulting level of pollution is higher than the socially optimum level in such situations and an over allocation of resources towards polluting activity becomes inevitable.

The market failure arising from excessive emissions leads to inefficiencies in resource allocation. As a solution economists suggest introducing a price on emissions to internalise the cost of pollutions thereby affecting the private cost. Two of the key policy instruments suggested are emissions tax and emissions trading. The former fixes the price of GHG and the latter the quantity of allowable emissions. Both instruments are advocated by economists because they appear to be more efficient in achieving environmental objectives at the least cost compared to the 'command-and-control' approach. With price on emissions, polluters are free to choose the level of reduction in emissions by comparing their own abatement cost with the price. In doing so, firms with lower abatement cost may reduce more emissions than those who incur higher cost to reduce emissions. The least cost solution is achieved where firms equate their marginal cost of abatement to the price of emissions.

Establishing markets for externalities goes back to Coase (1960) when he suggested that a solution could be reached by defining property rights on emissions or externalities. In an environment with negligible transaction costs, Coase points out that the parties – polluters and victims – can bargain to achieve a socially optimal level of externality no matter who held the initial property rights. According to Coase, socially optimal level of externality is found when marginal benefits equate to marginal cost of externality. Popular market-based instruments to control emissions have the Coasian flavour because his proposition leads to a market price for externality. Under the policy of emissions trading, governments can set caps on the total amount of GHG that can be emitted to the atmosphere. The cap is then converted into allowances giving the right to emit a given amount of emissions. Emission allowances usually known as permits are allocated to polluters either by way of an auction or free allocation. The polluters can sell their permits in another market (domestic or international) depending on the way the ETS is set up. Those polluters who can abate more than their respective allowances may sell the permits whereas those who experience high abatement costs may buy permits instead of engaging in costly emissions reductions. Thus an ETS in principle can achieve emissions reduction targets at the lowest cost by equalising marginal abatement cost among polluters.

An ETS places fewer burdens on the government or controlling authority to seek out where the least cost opportunities for emissions reduction exist because it relies on market forces to achieve the efficient price for permits. Hence many economists prefer the marketable permit mechanism to reduce GHG emissions (Tietenberg, 2000). The responsibility on the part of the government would rather be to distribute the right amount of permits or pollution rights to polluters (Coase, 1960; Dale, 1968). Marketable permit mechanism also allows policy makers to differentiate efficiency from equity issues and let the permit market decide where the most cost-effective abatement can be attained.

Figure 1: Cost-effectiveness of International Emissions Trading



Source: Adopted from Babiker et al. (2004).

Under certain assumptions, it is convenient to show graphically the cost-effectiveness of an international ETS when there are no other market distortions. For example, in Figure 1 we display an ETS involving two countries. The marginal abatement cost of emissions reduction in country 1 is given by MAC_1 and country 2 by MAC_2. We assume that both countries have emissions caps initially. They are expected to reduce emissions by Q without emissions trading where Q is a joint reduction target for countries 1 and 2 (Q_1, Q_2) such that $Q_1 + Q_2 = Q$. For convenience, it is assumed that $Q_1 = Q_2$. From Figure 1, it is clear that the marginal abatement cost in country 1 is higher than in country 2 which leads to the initial price difference for carbon ($P_1 > P_2$).

As country 1 appears inefficient in its abatement effort with higher carbon price, it now agrees with country 2 to form an ETS. By equalising marginal abatement costs between two countries through an ETS, the two countries now achieve joint optimal reduction level of Q* emissions with the carbon price of P*. In effect, the ETS allows country 1 to reduce emissions only by Q_{1T} and buy emissions permits from country 2 to meet its target. Likewise country 2 reduces emission by Q_{2T} and sells excess permits to country 1. It is clear from Figure 1 that both counties are better off after engaging in international emission trading compared to the no trading (autarkic) outcome. There is a net income gain for country 1 given by area A and for country 2 by area B.

Based on the above premises there is a vast array of empirical literature that encompasses the development and application of CGE models to assess the potential economic gains from ETS to meet the Kyoto targets of emissions reductions in different countries and regions. Previous work has mainly concentrated on the analysis of the European Union emissions trading scheme (EU-ETS). To place the present study in context, we review briefly some of the CGE studies that analysed the unilateral abatement actions and emissions trading. The literature belongs to two strands. One concentrates on using CGE modelling to examine the effects of meeting Kyoto targets at the global level either by unilateral emissions cuts or through emissions trading schemes. Many of these studies consider the European Union as a single bloc, trading permits with other regions. Such studies include Babiker et al. (2004), Bohringer (2002), Bohringer and Welsch (2004; 2006), Fisher and Fox (2007) and Takeda and Arimura (2014).

The studies in the other category examined emissions trading among the countries of the European Union without any consideration to trade between the EU and outside world. Kemfert et al. (2006) used a modified version of the GTAP-E model with version 6 of its database to analyse the abatement cost and welfare impact of the EU-ETS. They found that the real GDP increased in all regions while welfare gains mostly occurred in regions where high efficiency gains from emissions trading were experienced. Other studies of this kind include Viguier et al. (2003), Babiker et al. (2003), Bohringer and Lange (2005), Viguier et al. (2006) and Lokhov and Welsch (2008). The focus of these studies has been to analyse the allocation of emissions rights to energy intensive sectors of the EU countries. Some of these studies, including Kemfert et al. (2006), confirm that unfavourable terms of trade effects outweigh the benefits of emissions trading for some countries in the EU-ETS.

Even though Australia has been in front in making environmental policies to reduce emissions, economic modelling related to the global level ETS formulation with Australia being a partner has been limited. Adam et al. (2014) described the most comprehensive study that has ever been undertaken to project the outcomes of an ETS directly affecting the Australian economy. In this study, the ETS is featured as a part of a linking process between MMRF and GTEM models. In effect the carbon permit price is projected by GTEM and converted to real Australian dollar price through MMRF. The permit price begins at A$24 per tonne in 2012 and gradually increases over time to A$49 per tonne by 2030. An electricity sub-model, WHIRLYGIG, provides inputs to the MMRF modelling process by responding to the permit price. The study reports comprehensive environmental and economic projections on the Australian economy as a result of emissions pricing through a global ETS. Among other things, Australia's real GDP is projected to decline by 1.1 per cent by 2030 in response to the underlined environmental policy.

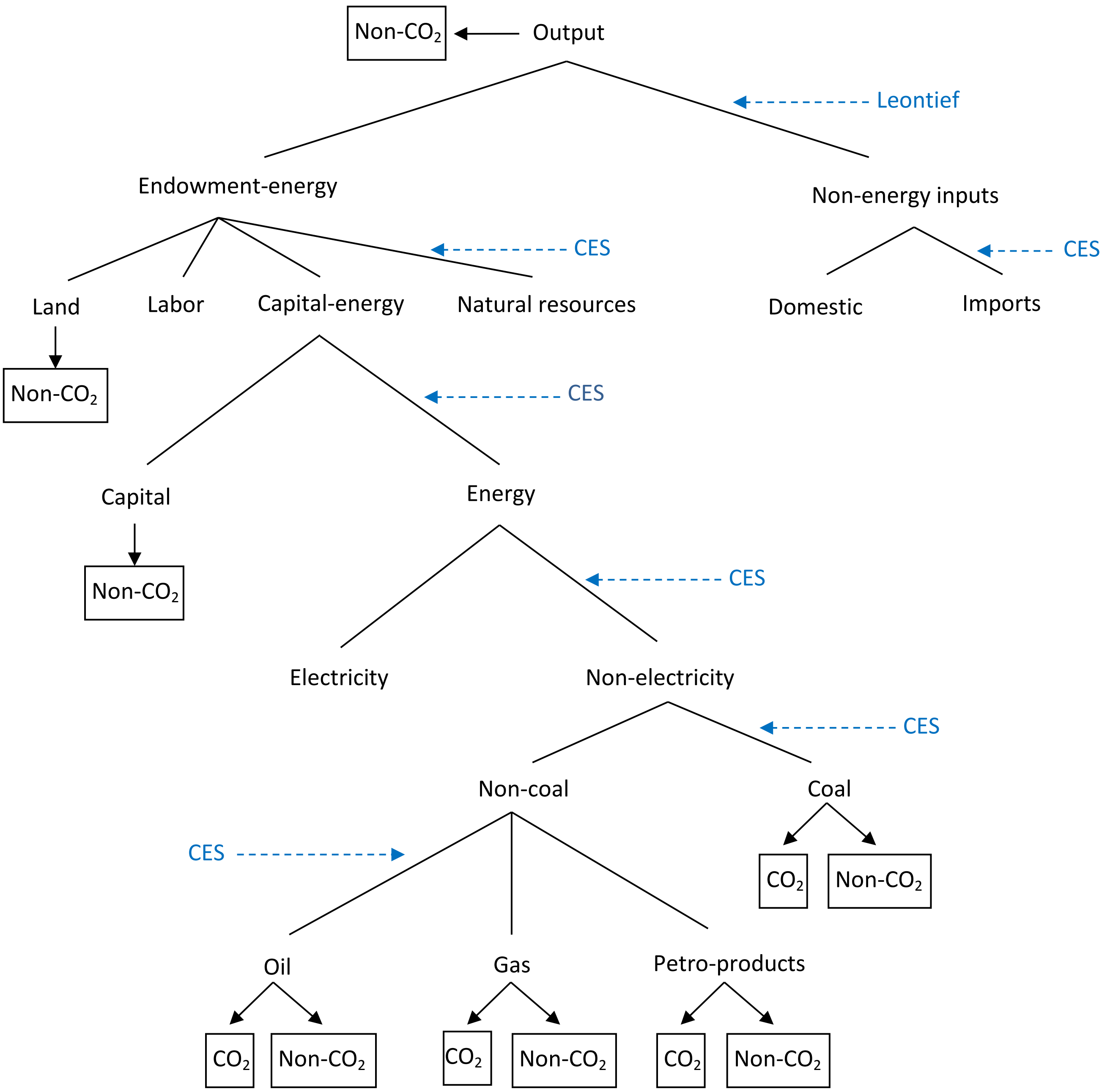
In the light of the existing literature, our study focuses on emissions trading in a broader and global framework by defining to include all Annex 1 counties into a global ETS. In doing so, we explicitly recognise key Annex 1 counties including Australia separately and EU as a single region within the trading block. While Annex 1 countries engage in emissions trading with each other, three major non-Annex 1 country emitters – China, India and South Korea – are assumed to carry out domestic emissions trading of their own. Our second scenario captures the idea that latter three emitters join Annex 1-ETS and form a single global ETS enabling us to examine the impact on marginal abatement cost if world decided to move in that direction. In consistent with previous literature, the model scenarios allow emissions trading between sectors of the economy as well as between sectors of all countries (regions) in the trading block.

3. Model Structure and Database

3.1 Model

The GTAP-E model developed by McDougall and Golub (2007) has been used in this paper. 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).

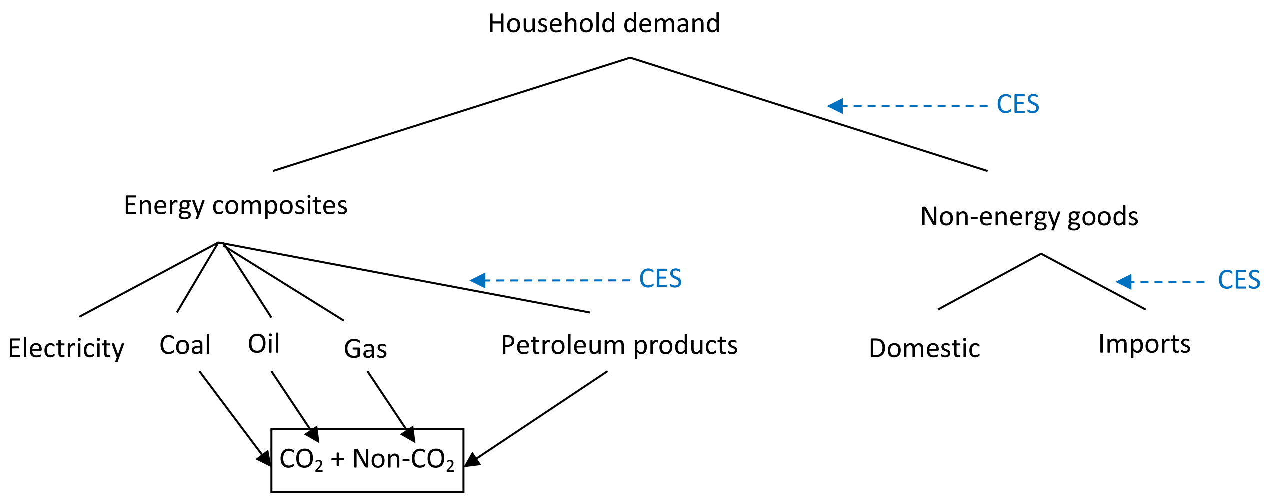
Figure 2: The Production Structure in GTAP-E Model



Similar to the GTAP model, GTAP-E also uses the nested Constant Elasticities of substitution (CES) production structure. This is briefly outlined in Figure 2. 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 2. 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 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 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.

Figure 3: GTAP-E Private Household Consumption Structure

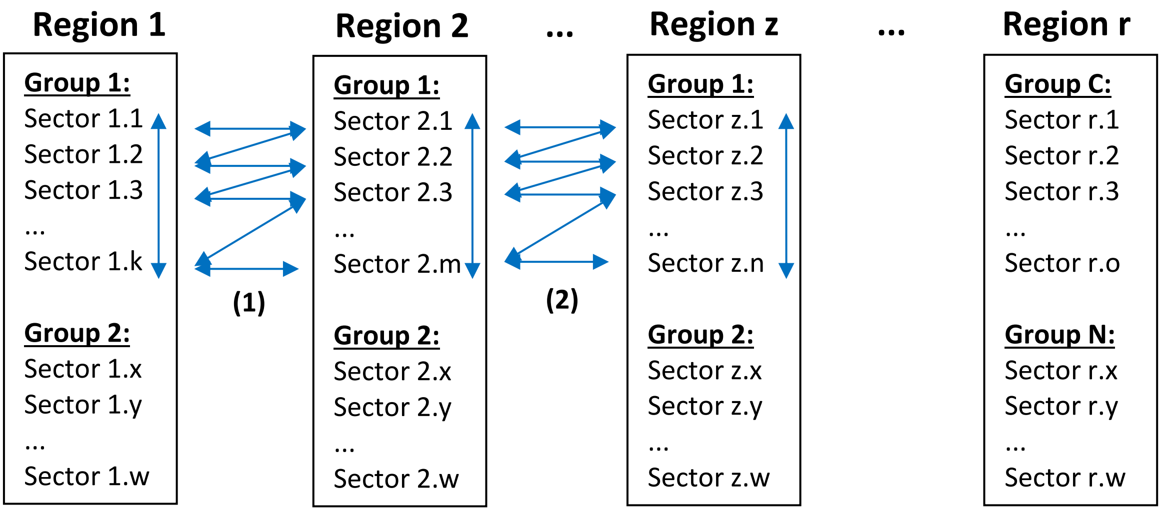


Household consumption structure, as shown in Figure 3, is designed in a different way. The first level of CES possibility is to select between non-energy goods and energy goods. At the second level of substitution, household can substitute away from coal for gas, oil, electricity and petroleum products when coal becomes more expensive relative to the other energy goods.

In the original GTAP-E database (release 8.1), there are only CO_2 emissions from combustion of oil, gas, petroleum products and coal. Hence, we have incorporated non-CO_2 emissions into the database in order to capture comprehensive emissions levels in the analysis. The non-CO_2 emissions data are also compiled by the GTAP group. As shown in Figure 2, non-CO_2 emissions also generated by combustion of oil, gas, petroleum products and coal. In addition, non-CO_2 emissions come from the uses of land and capital in the Agriculture sector. The non-CO_2 emissions are also released in production processes, shown as emissions from output production process in Figure 2, and uses of Chemical, rubber and plastic products, and Gas manufacture and distribution commodities. Non-CO_2 emissions also come from energy usage of households (Figure 3). In addition, CO_2 and non-CO_2 emissions are kept separately as shown in Figure 2, hence, the simulation results will report the fluctuations of CO_2 and non-CO_2 emissions by each agent independently. The total fluctuations of CO_2-e (CO_2 equivalent) by each agent are also reported. However, in the case of emissions trading or carbon tax scenario, both CO_2 and non-CO_2 emissions are traded together and are subject to a carbon price.

The GTAP-E model has been further modified to make the task manageable. For example, it now allows a simulation of domestic ETSs with selected industries and also places a carbon tax in focused industries. Figure 4 highlights the possible outcomes of the modified model, for example, when Region 1, Region 2 ... Region z have domestic ETSs, (1) and (2) links will not exist. In that case, only sectors in Group 1 of each of these regions trade together; sectors in Group 2 do not participate the domestic trading markets. At the same time, Region r, or any other regions, can solely have its own carbon tax applied for sectors in Group C only. In another scenario, Region 1, Region 2 ... Region z can join an emissions trading market, which

Figure 4: Possible scenarios in the modified GTAP-E model



allows their domestic ETS participating sectors to trade together, while Region r still has its own carbon tax. In addition, Region 1 and Region 2 can make an emissions trading market, while Region 3, 4 and 5, etc. can make another emissions trading market.

3.2 Database and parameters

The database for the simulations is taken from GTAP-E version 8.1 database. It also contains most up to date 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, 134 regions are aggregated into 10 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.

3.3 The emissions targets

According to the Copenhagen Accord regarding emissions targets for countries (UNFCCC, 2010a), we obtain the 2020 emissions targets relative to base year for Australia, Japan, United States and EU27 as shown in third column in Table 1. The 2020 emissions target for ROA1 region is an average target from its members. From these percentage emissions reduction targets, we have calculated the levels of emissions targets of these regions in 2020 except Australia[2], based on emissions published by the UNFCCC (2013).

China and India committed to reduce their emissions intensities of GDPs by 2020 relative to 2005 levels (UNFCCC, 2010b); hence, their 2020 emissions target levels are calculated in different way as outlined below:

$$\frac{CO2\_e_{2020}}{GDP_{2020}} = (1 - \text{emission intensity reduction}) * \frac{CO2\_e_{2005}}{GDP_{2005}}$$

$$\Leftrightarrow CO2\_e_{2020} = (1 - \text{emission intensity reduction}) * \frac{GDP_{2020} * CO2\_e_{2005}}{GDP_{2005}}$$

We obtain the GDP_{2005} of these two countries from World Bank (2014a). We predict GDP of China in 2020 based on its annual GDP growth rate in 2005 (World Bank, 2014b), while GDP of India in 2020 is forecasted by the World Bank (2014c). Emissions of China and India in 2005 are taken from UNFCCC (2014). Based on the emissions published by World Bank for period 2000-10, we obtain the emission growth rate for Korea in order to calculate emissions target level of Korea in 2020 relative to its BAU emission level.

Finally, all of these regional emissions target levels by 2020 will be reverted to present target levels in 2007, based on emissions growth rates in period 2000-10[3]. The final column in Table 1 presents the percentage reductions from emissions levels in the database 2007 to the present target levels above. It enables us to achieve the 2020 emissions targets of these regions by using the static GTAP-E model.

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[2] We do not calculate the 2020 emissions target for Australia as it was announced by the Government (Department of Environment, 2013). We use this emissions target (555 Mt CO2_e) for our calculation.

[3] In order to get emissions in the same period 2000-10, emissions for Australia, Japan, United States, EU27 and ROA1 are collected from UNFCCC, while emission of this period for China, Korea and India are gathered from World Bank.

Table 1: Emissions reductions from 2007 levels

Base year	Region	Copenhagen CO2_e Targets for 2020 relative to base year	Required Change in CO2_e from 2007 levels
2000	AUS	-5%	-8%
1990	JPN	-25%	-11%
2005	USA	-17%	-7%
1990	EU27	-30%	-10%
1990	ROA1	-22%	-3%
2005	CHN	-45%*	-9%
2020	KOR	-30%**	-14%
2005	IND	-25%*	-1%

*Note: * refers to a reduction of CO2_e per unit of its GDP relative to base year case. ** indicates a reduction relative to business as usual.*

4. Simulation Scenarios and Results

In our simulations we assume that each Annex 1 country designs its abatement policy to reduce emissions and to meet the Kyoto target by 2020. In addition, three major developing country emitters outside of Annex 1 (China, India, and South Korea) are assumed to take actions to honour their Copenhagen and Cancun pledges to reduce their emissions. There are no emissions restrictions imposed on oil exporting countries and rest of the world. Hence two ETS scenarios that are formulated for the present study are as follows:

S1- ETS Annex 1: All Annex 1 countries participate in an international emission trading scheme while China, India and South Korea engage in their own domestic emissions trading schemes.

S2- ETS Annex 1+: All Annex 1 countries continue their ETS and China, India and South Korea join that international ETS.

4.1 Results and Discussion

As outlined above, two ETS scenarios were simulated using the GTAP-E model and its latest version 8.1 database. On the basis of the modelling results, this section evaluates the potential economic and environmental effects of an emissions trading scheme at global level where Australia participates as a key Annex 1 country. When initial global ETS among Annex 1 countries are in operation, three of Australia's major trading partners undertake their own domestic ETSs that provide flexible trading environment to their industries under specific abatement targets. An international ETS creates a formal international carbon market leading to a common price for emissions permits that is determined by the supply of and demand for permits. A similar situation is experienced in China, India and South Korea within their

Table 2: Impact on Carbon (Permit) Price and Emissions Levels of ETS

	AUS	USA	EU27	JPN	RoA1	CHN	KOR	IND
	Carbon (Permit) Price (US$/t$CO_{2\text{-}e}$)							
S1- ETS Annex1	10.56	10.56	10.56	10.56	10.56	4.75	23.54	0.18
S2- ETS Annex1+	6.32	6.32	6.32	6.32	6.32	6.32	6.32	6.32
	International Emissions Trading Revenue (US$ million)							
S1- ETS Annex1	129.1	897.3	-2106.3	-682.2	1762.1	0.0	0.0	0.0
S2- ETS Annex1+	-46.2	-657.3	-1882.6	-546.6	487.9	1132.7	-273.2	1785.4
	Emissions Trading Volume (Mt$CO_{2\text{-}e}$)							
S1- ETS Annex1	12.2	85.0	-199.6	-64.6	166.9	0.0	0.0	0.0
S2- ETS Annex1+	-7.3	-103.9	-297.7	-86.4	77.2	179.1	-43.2	282.3
	Total $CO_{2\text{-}e}$ Emissions of the Whole Country (% change)							
S1- ETS Annex1	-10.2	-7.9	-5.4	-5.1	-8.3	-9.2	-13.6	-0.5
S2- ETS Annex1+	-6.4	-5.2	-3.4	-3.2	-5.3	-11.7	-4.6	-15.2
	Total $CO_{2\text{-}e}$ Emissions from Firm's Usage (% change)							
S1- ETS Annex1	-10.9	-9.5	-6.4	-5.9	-9.3	-9.7	-15.4	-0.5
S2- ETS Annex1+	-6.9	-6.2	-4.1	-3.7	-6.0	-12.3	-5.3	-16.3
	Total $CO_{2\text{-}e}$ Emissions from Household Usage (% change)							
S1- ETS Annex1	-0.1	0.3	0.3	0.5	0.2	1.3	1.5	0.3
S2- ETS Annex1+	0.0	0.2	0.2	0.4	0.1	1.7	0.6	1.4
	Total $CO_{2\text{-}e}$ Emissions from Government Usage (% change)							
S1- ETS Annex1	2.0	1.4	0.8	1.0	0.3	-0.1	2.6	0.2
S2- ETS Annex1+	1.1	0.9	0.5	0.6	0.2	-0.3	0.8	1.8

domestic carbon markets where a price for carbon permits is determined by demand and supply forces. Eventually when both Annex 1 and three major non-Annex 1 country emitters participate in a single international ETS, a common permit price emerges. It is expected that different sectors in different countries react to the permit price, and relative commodity price shifts which may eventually induce changes in GHG emissions levels. Reported in this section are the important environmental, macroeconomic, welfare and industry level effects of carbon pricing via international emissions trading.

4.1.1 Environmental Impacts of Emissions Trading

The economy wide environmental effects of the two ETS scenarios are reported in Table 2. A permit price of US$10.56 emerged under the ETS of Annex 1 countries when they engage in emissions trading according to their relative strength in demand for and supply of permits. Note that China, India and South Korea have their own domestic ETS functioning concurrently in the first scenario hence they experience three different permit prices; India's permit price is the lowest (US$0.18) followed by a rather moderate price in China (US$4.75). Conversely, South Korea's domestic carbon market is relatively tight and the price of a permit in its market has reached US$23.54 as a result. In the event of these three non-Annex1 emitters join the international ETS (scenario S2), the permit price is dropped dramatically to US$6.32.

It is apparent that China and India's entry to the world carbon market has a significant impact on the permit price and all other participants in the global ETS benefit from it because it improves their ability to lower the cost of abatement by trading through a larger international ETS. The cost of abatement in China and India are relatively low and they can reduce emissions beyond their quota leaving a surplus of permits to sell internationally. It is also evident that larger emitters can drive the international carbon market resulting in a permit price closer to their domestic ETS price.

In scenario S1, Australia, USA and RoA1 become sellers whereas EU27 and Japan become buyers of emissions permits in their attempt to meet the abatement targets. This market outcome has changed dramatically as a result of an enlarged international ETS to include three major non-Annex 1 emitters - China, India and South Korea. As can be seen from the projections in Table 2, all Annex 1 countries except RoA1 group become net buyers of permits; China and India benefit from joining the international ETS as they become net sellers of permits globally raising substantial revenue from it. According to model projections, India raises US$ 1.8 billion revenue while China records US$ 1.1 billion. Due to high cost involved in South Korea to abate its own emissions domestically, it ends up purchasing 273 Mt of permits from the international market to meet its target. Even though Australia and USA are net buyers, their purchases of permits are rather small relative to their quota. EU27 finds it cheaper to buy permits in the international market under the new permit price (US$ 6.32) at a higher level than in scenario S1; the results indicate its purchase of permits rises from 199 Mt in S1 to 297 Mt in S2 while the overall cost of purchasing falls. Consequently it can benefit through cost efficiencies and meet the Kyoto target at a lower cost by becoming a partner of a larger international ETS.

Table 2 also reports other useful projections regarding the changes in emissions levels for the entire economy, firms, households and the government activities. Economy wide changes in emissions in Table 2 in response to the international emissions trading can be compared with targeted emissions reductions in Table 1. In scenario S1, Australia, USA, and ROA1 reduce their emissions beyond their quotas so that they become net sellers of permits. In fact Australia and RoA1 experience better opportunities than USA to cut emissions at a lower cost when Annex 1 countries engage in trading among themselves. However the situation changes dramatically when three non-Annex 1 countries joined the ETS. As China and India experience higher level emissions reductions than target cuts enabling them to sell permits at the new price which is much lower than when Annex 1 countries trade alone, Australia and USA turn out to be net buyers of permits. Furthermore, EU27 and Japan purchase more permits than before taking the advantage of low permit price. For RoA1 countries opportunities to sell permits are reduced with the entrance of low cost abatement countries - China and India. South Korea also enters the international ETS as a net buyer of permits to meet its abatement target.

Projections in Table 2 show that emissions by firms are reduced in line with national trends while emissions at household and government levels are increased. This is because the latter two agents do not face the tax and they do not involve in emissions trading. Interestingly, China’s household related emissions increase slightly more than other countries after joining the international ETS. Two factors can be responsible to this. First, carbon pricing reduces the prices of some of the energy sources like coal, oil and gas with the general trend towards reduced demand for energy which in turn stimulates household demand for those energies. Second, household demand for such goods may be price elastic and consumers substitute these goods for now more expensive electricity.

Table 3 reports emissions trading volumes by individual sectors in each region under two ETS scenarios. In the table, sectors with positive numbers indicate sellers and with negative numbers buyers in the carbon market. Under scenario 1, sectoral emissions trading activities are higher in USA (210 Mt. in Electricity alone) than any other region and RoA1 countries come second. Across all regions except Japan, the electricity sector turns out to be the most active seller of permits indicating its greater potential for abatement through the implementation of an international ETS. Why does this sector have so much of surplus permits? This is partly due to its low marginal abatement cost in general and ability to switch to less emissions intensive energy sources to generate electricity. For example, in the USA, 59% of electricity is generated from renewables, nuclear power and natural gas. In EU27, 50% of electricity now comes from renewables and nuclear source (World Nuclear Association, 2015). The electricity sector in Australia also shows higher potential to sell permits (21 Mt.) in scenario 1 despite its high fossil fuel dependency for electricity. The Japanese electricity generation is highly fossil fuel intensive and its capacity for abatement through this sector is not that great. Hence the sector becomes a net buyer of permits in Japan. It is also worth noting that the sector 'Agriculture' is a net buyer of permits in most of the Annex 1 countries. In addition, 'Oil products' and 'Chemical & rubber' sectors are also significant net buyers of permits in the USA and EU27. These sectors have higher marginal abatement cost hence it is cheaper for them to acquire permits from the international carbon market in order to meet their targets.

For China, India, and South Korea, emissions trading volumes reported in Table 3 under scenario 1 are due to their domestic ETS activities. Again it is clear that 'Electricity' is a net seller in all three countries. The sectors 'Coal' and 'Mineral products' are also significant net sellers in the domestic carbon market in China due to their capacity to engage in cheaper abatement activities relative to other sectors. In common with Annex 1 regions, 'Agriculture' is a net buyer of emissions permits to meet the targets.

Entrance of China, India and South Korean into the world carbon market (scenario 2) has discernible impact globally. All Annex 1 countries tend to change their abatement behaviour taking the advantage of lower permit price emerged from permits sales by China and India. Noticeably, Australia, USA, and RoA1 counties withdraw their permit sales dramatically, especially in 'Electricity'. Furthermore, EU27 which was a net seller of permits through 'Electricity' has now become a net buyer while Japan increases its purchase of permits through this sector. Hugely expanded permit sale by China and India to the world carbon market has a greater influence on Annex 1 countries as evidenced by the increased permits acquisition in ‘Agriculture’.

Levels of emissions reduction for individual sectors in each country for two scenarios are reported in Table 4. These reduction rates are to be understood in relation to country level target cuts of emissions in Table 1 and emissions trading volumes shown in Table 3. Notice that in our simulations target cut for each industry is the same as the target cut for the country that industry belongs to. Hence when emissions reduction rates are greater than target cut for industries, such industries become sellers in the carbon market as they have excess permits. Similarly those sectors who cannot achieve the target cut due to high abatement cost or any other reason, their emissions reduction rates are lower in Table 4. Hence they become buyers of permits as displayed in Table 3. In Australia, higher emissions reductions occur in sectors such as ‘Electricity’, ‘Other metals’, ‘Mineral products’, ‘Wood and paper products’, and ‘Coal’. The agricultural sector cannot meet its target and hence becomes a buyer of permits from the international market.

From Table 4, we can make similar observations in other countries’ emissions reductions by sectors. As far as the electricity sector is concerned, except Japan, every other region appears to reduce emissions beyond the target allowing the sector to sell permits. This sector is highly emissions intensive in many countries and produces electricity mostly using fossil fuel. At the same time it presents opportunities for input substitution in generating electricity; renewables and gas are substituted for fossil fuel which results in higher emissions reductions relative to other sectors. Another factor could be that its marginal cost of abatement is low in comparison to other sectors allowing high level emissions reductions.

Interestingly, China and India’s entry into the international carbon market tends to alter the emissions reductions pattern for many regions. Majority of sectors in both countries tend to abate beyond their targets in scenario two which make them sellers of permits to the international market. Hence many other regions find it now cheaper to buy permits to meet the target rather than engaging costly emissions reductions domestically. Lower permit price in scenario two influences many countries (and sectors) to become buyers rather than sellers of carbon permits in the end. It is evident from these results that larger emitters in an

Table 3: Emissions Trading Volumes by Sector in each Region ($MtCO_{2-e}$)

Region	AUS		USA		EU27		JPN		RoA1		CHN		KOR		IND	
Scenario	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Agriculture	-4.9	-6.1	-30.9	-35.6	-29.6	-40.1	-5.2	-5.3	1.8	-2.1	-111.3	-105.6	-3.1	-3.3	-2.5	2.1
Coal	0.5	-1.2	5.8	2.3	0.5	-1.2	0.0	0.0	6.9	3.9	27.1	40.9	0.0	-0.1	0.3	8.9
Crude Oil	-0.1	-0.1	-3.1	-3.3	-0.8	-0.8	0.0	0.0	-2.0	-2.8	-0.9	-0.5	0.1	0.0	0.0	0.0
Natural gas	-0.4	-0.5	-2.5	-5.8	-2.9	-3.8	0.0	-0.1	5.9	1.3	4.6	6.6	0.6	0.2	0.1	0.9
Other Minerals	-0.1	-0.3	0.0	0.0	-0.4	-0.5	-0.2	-0.2	1.1	0.3	0.1	0.6	0.0	0.0	0.0	0.1
Food	0.0	-0.1	0.7	-1.4	-2.5	-3.8	-0.9	-1.0	0.7	0.3	3.8	6.1	-0.2	-0.3	-0.3	0.6
Textile & leather	0.0	0.0	0.0	-0.3	-0.6	-0.9	0.0	0.0	0.1	0.0	4.3	6.3	-0.1	-0.4	0.0	0.6
Wood, paper products	0.1	0.0	0.9	-1.5	-1.7	-2.6	-0.3	-0.7	0.7	0.3	3.2	5.2	-0.2	-0.4	0.0	2.0
Oil products	-0.7	-0.9	-11.6	-13.0	-14.0	-15.1	-3.3	-3.4	-0.4	-1.9	-6.4	-5.4	-2.1	-2.7	-0.4	0.1
Chemical & rubber	-0.2	-0.3	-4.9	-8.7	-15.7	-17.5	-5.5	-6.2	0.1	-0.7	-11.5	-4.7	-1.5	-2.1	-0.4	3.5
Mineral products	0.3	0.0	3.2	-0.1	-4.3	-7.1	-0.5	-1.5	3.2	1.6	20.1	35.2	1.9	-1.1	0.2	13.9
Ferrous metals	-0.1	-0.1	-0.4	-1.4	-3.7	-5.4	-3.7	-4.7	3.5	1.5	-6.9	-0.2	-0.2	-1.6	-0.3	13.5
Other metals	0.9	0.1	-0.7	-1.2	-1.5	-1.8	-0.3	-0.3	0.7	0.2	-0.6	0.8	-0.1	-0.1	-0.1	0.7
Metal products	0.0	0.0	-0.2	-0.4	-0.6	-0.8	-0.3	-0.4	0.2	0.1	0.0	0.3	-0.1	-0.1	0.0	0.7
Motor vehicles & parts	0.0	0.0	-0.5	-1.3	-1.7	-2.4	-0.3	-0.4	0.6	0.3	0.3	1.9	-0.2	-0.4	0.0	0.2
Electronic equipment	-0.2	-0.2	-7.7	-8.4	-3.3	-3.4	-4.1	-4.2	-0.3	-0.4	-1.2	-1.1	-0.9	-1.1	0.0	0.0
Other manufacturing	0.0	0.0	0.0	-0.1	-0.2	-0.3	-0.2	-0.2	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.4
Electricity	21.1	7.6	210.8	73.4	11.5	-46.2	-11.8	-26.8	127.1	73.5	118.6	227.9	17.9	-12.8	5.0	217.2
Transport services	-2.8	-3.9	-53.8	-72.0	-101.9	-113.2	-18.2	-19.9	11.9	1.4	-20.9	-17.1	-7.5	-11.0	-1.3	1.9
Other services	-1.1	-1.2	-19.9	-24.9	-26.2	-30.2	-9.7	-11.1	4.8	0.3	-22.2	-18.2	-4.4	-5.6	-0.5	14.5

Table 4: Changes in Emissions level by Sector in Response to Emissions Trading (% Changes)

Region	AUS		USA		EU27		JPN		RoA1		CHN		KOR		IND	
Scenario	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Agriculture	-3.3	-2.1	-2.2	-1.4	-5.6	-3.5	-0.3	-0.2	-3.9	-2.4	-1.2	-1.6	-1.2	-0.3	-0.1	-1.0
Coal	-10.4	-3.7	-18.0	-11.9	-12.4	-7.9	-11.9	-7.3	-18.5	-11.9	-17.7	-21.8	-17.2	-6.2	-1.8	-38.6
Crude Oil	-1.8	-1.5	-1.2	-0.8	-2.6	-1.7	-5.5	-3.5	-1.7	-1.1	-6.9	-8.2	-58.4	-16.7	-1.2	0.0
Natural gas	-3.4	-1.6	-6.2	-3.8	-4.7	-2.8	-4.0	-2.3	-6.6	-3.9	-26.6	-33.7	-84.5	-31.8	-0.9	-7.8
Other Minerals	-6.7	-4.5	-9.8	-6.2	-4.9	-3.1	-1.7	-0.9	-6.7	-4.1	-9.9	-12.9	-5.9	-1.3	-0.5	-4.2
Food	-9.5	-6.1	-9.1	-5.8	-6.5	-4.1	-2.6	-1.5	-11.3	-7.2	-16.6	-20.7	-6.8	-1.9	0.3	-2.6
Textile & leather	-8.9	-5.8	-7.6	-4.7	-5.7	-3.4	-3.1	-1.9	-10.9	-6.9	-18.5	-22.7	-13.5	-4.2	-0.2	-13.7
Wood, paper products	-12.8	-8.3	-9.3	-5.9	-6.7	-4.2	-9.7	-6.2	-8.6	-5.3	-16.9	-21.2	-7.2	-1.9	-0.9	-28.4
Oil products	-2.9	-1.8	-1.8	-1.0	-1.7	-0.9	-1.4	-0.9	-2.9	-1.7	-2.7	-3.8	-4.2	-0.9	0.4	-0.8
Chemical & rubber	-4.7	-3.0	-5.4	-3.3	-2.4	-1.4	-2.9	-1.7	-3.3	-1.9	-6.2	-8.3	-5.2	-1.1	0.4	-9.3
Mineral products	-12.6	-8.1	-12.3	-7.9	-7.1	-4.4	-10.1	-6.4	-12.1	-7.7	-14.9	-18.9	-26.3	-9.3	-0.9	-27.9
Ferrous metals	-5.8	-3.5	-6.9	-4.1	-6.1	-3.6	-4.9	-3.0	-9.9	-6.0	-7.3	-9.6	-14.1	-4.2	-0.1	-22.6
Other metals	-13.9	-9.0	-5.3	-3.1	-3.9	-2.3	-3.1	-1.6	-6.5	-3.9	-8.5	-11.2	-8.3	-1.9	1.5	-18.7
Metal products	-6.8	-4.1	-6.3	-3.8	-5.6	-3.3	-5.6	-3.4	-9.1	-5.5	-9.5	-12.3	-7.9	-2.1	-0.3	-19.4
Motor vehicles & parts	-6.3	-3.9	-6.5	-3.9	-5.8	-3.6	-3.8	-2.3	-10.9	-6.8	-10.3	-13.2	-9.3	-2.8	0.4	-8.5
Electronic equipment	0.2	0.1	-1.4	-0.8	-0.8	-0.5	-1.1	-0.7	-1.5	-0.9	-2.6	-3.3	-2.2	-0.8	0.6	-1.5
Other manufacturing	-8.0	-4.9	-7.8	-4.9	-3.8	-2.3	-2.4	-1.3	-9.0	-5.6	-9.7	-12.3	-16.1	-5.6	-0.2	-17.7
Electricity	-18.3	-11.9	-16.6	-11.0	-12.0	-7.8	-9.5	-6.2	-15.8	-10.5	-13.7	-17.4	-24.6	-8.9	-1.2	-28.6
Transport services	-4.2	-2.5	-3.7	-2.2	-2.4	-1.4	-2.3	-1.3	-5.6	-3.5	-3.2	-4.4	-6.0	-1.5	0.6	-2.3
Other services	-2.3	-1.4	-3.1	-1.9	-3.1	-1.9	-3.2	-1.9	-5.3	-3.3	-3.6	-4.7	-4.1	-1.1	-0.2	-8.7

international ETS can drive the carbon market to a more efficient level with significant achievements in cost efficiencies to almost every market participant.

4.1.2 Macroeconomic and Welfare Impacts

Macroeconomic projections of the two ETS scenarios are shown in Table 5. When only Annex 1 countries are in an international ETS (scenario 1), they all experience a negative impact on their real GDP in response to the carbon pricing policy. Australia and RoA1 countries are the highest losers of real GDP (1.03 and 1.24 per cent respectively). In the meantime, China, India and South Korea have delivered a mixed outcome from their respective domestic ETS schemes. Interestingly, India increases its real GDP slightly while China and South Korea have their real GDP reduced substantially. There is a significant turnaround of real GDP projections when these three counties joined the international ETS (scenario 2). All Annex 1 countries have now almost halved their real GDP loss with a lower permit price stemmed from China and India's permit sales to the world carbon market. However these adjustments come at a cost to China and India; former has a higher loss in real GDP and the latter reports a GDP decline as opposed to a slight increase realised under the domestic ETS.

Table 5: Macroeconomic Impacts of the ETS (percentage changes)

	AUS	USA	EU27	JPN	RoA1	CHN	KOR	IND
				Real GDP				
S1- ETS Annex1	-1.03	-0.43	-0.39	-0.35	-1.24	-1.13	-1.53	0.12
S2- ETS Annex1+	-0.59	-0.26	-0.22	-0.19	-0.75	-1.49	-0.41	-0.88
				Export Volume				
S1- ETS Annex1	-1.88	-1.26	-0.68	-0.97	-1.25	-1.25	-2.48	0.21
S2- ETS Annex1+	-1.05	-0.70	-0.39	-0.59	-0.71	-1.60	-0.72	-1.53
				Import Volume				
S1- ETS Annex1	-1.78	-0.72	-0.63	-0.97	-1.34	-1.32	-2.20	0.13
S2- ETS Annex1+	-1.01	-0.48	-0.38	-0.62	-0.82	-1.53	-0.76	-0.41
				Consumer Price Index				
S1- ETS Annex1	0.06	0.40	0.41	0.39	0.40	0.42	0.58	0.29
S2- ETS Annex1+	0.13	0.29	0.30	0.28	0.29	0.43	0.26	0.53
				Terms of Trade				
S1- ETS Annex1	-0.02	0.22	0.08	0.17	-0.09	0.15	0.45	0.00
S2- ETS Annex1+	0.05	0.11	0.04	0.08	-0.07	0.27	0.07	0.30

An international emission trading reduces world trade volumes (both exports and imports) that are likely to have contributed to the real GDP loss. Australia is projected to have the highest percentage loss in exports and imports compared to its other Annex 1 partners. Carbon price through the ETS has a modest inflationary effect due to increase in cost in all the countries resulting a loss in competitiveness. This in turn has a negative influence on exports and imports in Australia and other countries. China and India are worse off in terms of their trade volumes after joining the international ETS whereas South Korea improves its trading position. For South Korea, transition from domestic to an international ETS reduces its cost to meet the emissions reduction target as the permit price per tonne fell from US$23.54 to US$6.32. But on the other hand China and India face higher permit price compared to their previous domestic ETS outcomes. By selling permits, a country may push its carbon price above the autarkic experience and environmental outcomes are largely driven

Table 6: Impact on Welfare of ETS (percentage change)

	AUS	USA	EU27	JPN	RoA1	CHN	KOR	IND
	Real Household Consumption							
S1- ETS Annex1	-0.74	-0.24	-0.26	-0.16	-0.97	-0.45	-0.77	0.36
S2- ETS Annex1+	-0.42	-0.16	-0.15	-0.09	-0.61	-0.56	-0.24	-0.23
	Real Wage (Skilled Labour)							
S1- ETS Annex1	-1.20	-0.52	-0.44	-0.34	-1.46	-1.24	-1.53	0.15
S2- ETS Annex1+	-0.68	-0.31	-0.25	-0.19	-0.88	-1.63	-0.44	-0.88
	Real Wage (Unskilled Labour)							
S1- ETS Annex1	-1.18	-0.51	-0.44	-0.34	-1.44	-1.31	-1.47	0.16
S2- ETS Annex1+	-0.67	-0.31	-0.25	-0.19	-0.89	-1.75	-0.42	-0.95
	Real Land Rent							
S1- ETS Annex1	-7.44	-5.32	-2.28	-1.09	-3.43	-4.33	-4.39	0.51
S2- ETS Annex1+	-4.88	-3.31	-1.40	-0.67	-2.15	-6.07	-0.91	-2.36
	Equivalent Variation (EV) (US$ million)							
S1- ETS Annex1	-5,079	-26,497	-33,348	-5,175	-29,613	-11,645	-6,200	840
S2- ETS Annex1+	-2,818	-17,227	-19,141	-2,945	-18,504	-14,399	-1,915	-2,032
	EV as a Percentage of GDP							
S1- ETS Annex1	-0.59	-0.19	-0.20	-0.12	-0.78	-0.33	-0.59	0.07
S2- ETS Annex1+	-0.33	-0.12	-0.11	-0.07	-0.49	-0.41	-0.18	-0.16

by the marginal abatement cost of the dominant participants in the ETS (see Figure 1)[4]. In the case of having an international ETS with all Annex 1 countries, China, India and South Korea, there is a terms of trade improvement for all but RoA1 region. This is largely attributed to the reduced exports by all participants in the ETS.

A number welfare related projections due to emissions trading are reported in Table 6. In both scenarios, Australia is shown to have a larger negative impact in real household consumption and equivalent variation (EV) than most of the Annex 1 countries. In fact Australia's position only second to RoA1 regions. Among Annex 1 countries, welfare cost measured in terms of EV as a percentage of GDP varies from -0.12 per cent to -0.78 per cent in Scenario 1 and -0.12 per cent to -0.49 per cent in Scenario 2. Non-Annex 1 partners- China, India and South Korea- show varying negative welfare effects. India which gained from its domestic ETS with the lowest permit price turns out to be a loser of welfare after joining the international ETS. China's welfare loss is further accelerated after it becomes a partner to an international ETS whereas South Korea seems to have improved. When we compare welfare changes of individual participants in an international ETS with their respective permit trade outcomes, we can observe that net sellers of permits tend to become losers from international emissions trading whereas net buyers of permits emerge as winners from the carbon market[5]. Hence it is reasonable to conclude that income gains from exporting permits are outweighed by negative effects of price changes (and costs) arising from the higher carbon price for such net seller countries.

Real wages of both skilled and unskilled labour, and rent on land are negatively affected by international emissions trading. This is caused by the inflationary pressure brought about by the carbon price which in turn reduces exports. The improvement in terms of trade is insufficient to outweigh the effects of cost increases on real factor prices in all the economies after the ETS comes into operation. However things are slightly different when number of market participants is higher, the negative impact on real wages and real rentals reduces because of the lower permit price.

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[4] See Babiker et al. (2004) for the EU experience of permit sales on carbon price.
[5] See Babiker et al. (2004) for similar findings in the case of EU-ETS.

Table 7: Changes in Output Level by Sector in Response to Emissions Trading (% Changes)

Region	AUS		USA		EU27		JPN		RoA1		CHN		KOR		IND	
Scenario	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Textile and leather	1.2	0.6	-0.5	-0.3	-0.3	-0.1	-0.3	-0.1	-0.1	0.0	-0.9	-1.1	-3.6	-0.9	0.0	-0.7
Electronic equipment	0.2	0.1	-1.2	-0.6	-0.6	-0.3	-0.9	-0.6	-1.0	-0.6	-1.1	-1.3	-1.8	-0.7	0.6	-1.5
Motor vehicles & parts	-0.1	-0.2	-0.7	-0.4	-0.7	-0.4	-0.9	-0.5	-1.1	-0.6	-1.9	-2.5	-2.6	-0.9	0.3	-1.5
Chemical & rubber	-0.2	-0.2	-1.1	-0.6	-0.4	-0.1	-0.5	-0.2	-2.2	-1.2	-1.9	-2.8	-3.0	-0.3	0.7	-1.8
Wood, paper products	-0.4	-0.3	-0.6	-0.3	-0.5	-0.3	-0.5	-0.3	-1.2	-0.7	-1.3	-1.8	-2.2	-0.5	0.2	-1.7
Ferrous metals	-0.5	-0.3	-0.8	-0.4	-0.6	-0.2	-0.9	-0.4	-3.3	-1.8	-1.9	-2.8	-4.0	-0.6	0.8	-2.0
Other manufacturing	-0.6	-0.3	-0.3	-0.1	-0.4	-0.2	-0.6	-0.3	-1.0	-0.5	-1.3	-1.6	-2.0	-0.5	0.2	-1.3
Metal products	-0.6	-0.3	-0.7	-0.4	-0.5	-0.2	-0.6	-0.3	-0.9	-0.4	-2.0	-2.7	-2.4	-0.6	0.3	-1.5
Other services	-0.9	-0.5	-0.4	-0.2	-0.4	-0.2	-0.4	-0.2	-1.2	-0.7	-1.3	-1.7	-1.5	-0.4	0.1	-0.9
Crude Oil	-0.9	-0.9	-0.7	-0.4	-1.3	-0.8	-5.5	-3.5	-1.3	-0.9	-1.9	-1.9	-55.4	-15.2	-1.0	1.0
Mineral products	-0.9	-0.5	-0.8	-0.4	-0.4	-0.1	-0.6	-0.2	-1.6	-0.9	-1.6	-2.1	-3.3	-0.6	0.3	-1.3
Food	-0.9	-0.6	-0.7	-0.4	-0.4	-0.3	-0.3	-0.1	-0.8	-0.5	-0.6	-0.8	-1.0	-0.3	0.0	-0.4
Transport services	-1.0	-0.6	-1.0	-0.6	-0.7	-0.4	-0.4	-0.3	-1.6	-1.0	-1.3	-1.7	-1.9	-0.5	0.3	-0.9
Agriculture	-1.6	-1.1	-1.4	-0.8	-0.7	-0.4	-0.1	-0.1	-0.9	-0.5	-0.6	-0.8	-0.6	-0.1	-0.1	-0.4
Natural gas	-2.6	-1.2	-6.1	-3.7	-4.4	-2.6	-4.0	-2.3	-5.2	-3.0	-20.2	-26.0	-84.5	-31.8	-0.9	-7.5
Oil products	-3.0	-1.8	-1.8	-1.0	-0.9	-0.5	-1.0	-0.6	-2.9	-1.7	-2.2	-3.0	-3.1	-0.6	0.5	-0.8
Other Minerals	-3.2	-2.4	-0.9	-0.5	-0.4	-0.3	-0.6	-0.3	-2.9	-1.7	-1.8	-2.6	-3.0	-0.7	-0.7	-2.2
Other metals	-7.4	-4.8	-1.8	-0.9	-0.4	-0.1	-0.5	0.0	-3.7	-2.1	-2.2	-3.3	-1.2	0.3	2.1	-3.8
Electricity	-8.8	-5.5	-5.4	-3.4	-2.6	-1.6	-2.5	-1.5	-5.5	-3.4	-5.6	-7.3	-9.1	-2.7	0.2	-4.4
Coal	-9.6	-3.3	-17.7	-11.7	-12.1	-7.7	-11.9	-7.3	-16.7	-10.8	-12.2	-15.1	-16.4	-6.0	-1.7	-37.6

4.1.3 Sectoral Output Results

In Table 7 we compare the sectoral output projections under the two ETS scenarios. For Australia, which ever level the ETS is formed, there is a significant negative impact on outputs of resource based sectors. Most notable are ‘Coal’, ‘Natural gas’, ‘Other minerals’, ‘Oil products’, ‘Other metals’, and ‘Electricity’ (see last six sectors in Table 7). With the exception of the electricity sector, all these sectors are trade exposed, and characterised by high emissions intensity generally. The costs of production in these sectors are higher due to carbon permit price arising from the ETS. Additionally, trade exposed sectors are faced with reduced competitiveness and international demand for their outputs as buyers of Australia’s resource goods, who also face the carbon price being participants of the ETS, substitute away from emissions intensive energy sources to reduce their own cost. ‘Textile & leather’ and ‘Electronic equipment’ sectors experience gains in output since they uses less energy intensive inputs. The rest of the sectors react with moderately reduced outputs in different proportions under the ETS. The output projections under scenario 2 show that Australia benefits from the lower permit price when China and India sell carbon permits in the international market. Many resource based sectors tend to reduce their output loss by purchasing permits from these two countries at a lower permit price.

The change in outputs of sectors in other Annex 1 countries is somewhat similar to Australia’s outcome. Main resource based sectors which carry high emissions are shown to have their output declined consistently. Supply of ‘Electricity’ is reduced across the board in all the countries reducing demand for key energy sources such as ‘Coal’, ‘Natural gas’ and ‘Oil products’. The general increase in prices and costs has affected almost every firm in the individual sectors resulting output contractions. When the three non-Annex 1 countries joined the international ETS, their sectors’ output responses change significantly compared to their situation under the domestic ETS. Their agreement to meet the emissions abatement targets in an international ETS puts pressure on sectors and the permit price movement from low to high has imposed an additional cost on producers, particularly in China and India. It appears that production levels in these two countries contract more than under the domestic ETS. On the other hand, Korea is a winner from an international ETS as the permit price it faces has dropped dramatically (from US$23.54 to US$6.32), lowering its cost on abatement. Hence outputs in Korea are reduced less compared to what they experience in the domestic ETS. This is particularly true in its ‘Natural gas’ and ‘Crude oil’ sectors.

5. Concluding Remarks

In this paper we have used a global CGE model, namely GTAP-E, to project the economic and environmental impact of an international emissions trading scheme with special reference to Australia. It is our belief that GTAP-E is well suited for this task as emissions represent a global externality and policies to combat such externality need to be examined within a global modelling framework. Our work has been further enhanced by the availability of non-CO_2 emissions data compiled by the GTAP group. The original database was modified to incorporate non-CO_2 emissions and to interpret final emissions in terms of $CO_{2\text{-}e}$. In addition, the modifications to the model allow us to undertake simulations of domestic ETSs with selected economies and industries concurrently with international ETS. The paper illustrates that this new feature has broaden the application of GTAP-E for environmental policy analysis.

The paper has examined two international emissions trading scenarios leading to two significantly different permit prices. In the first, all Annex 1 countries are joined together to form a global ETS to meet their respective Kyoto targets. This kind of global climate agreement produces a permit price of US$10.56 per tonne. In the second, three major non-Annex 1 emitters – China, India, and South Korea – also joined the international ETS of Annex 1 counties. Particularly, with the entrance of China and India into the international carbon market, the global price of emissions permits collapse to a substantially low price of US$6.32 per tonne. Consistent with priori expectations, this price is above the domestic permit price in China and India.

The analysis with the GTAP-E model leads to several important findings. For Australia, the ETS appears to be an attractive option since this level of emissions tax represents a substantially reduced abatement cost to polluting industries. In particular, under scenario 2, the low emissions permit price (US$6.32) allows Australia to undertake 80 per cent of its abatement domestically and import permits from foreign counties to cover the remaining 20 per cent of the abatement target. Depending on the level of international participation in the ETS, Australia's GDP is likely to be reduced in between 1 per cent and 0.6 per cent compared to the base year (2007). This loss of GDP is mainly due to the negative impact on international trade imposed by the carbon price. Nevertheless the decline in real household consumption (0.7 per cent to 0.4 per cent) is less than the GDP loss which can be attributed to the slight improvement in the terms of trade. In the event of a global agreement to reach a price for emissions permits through the ETS, Australia's resource exports are like to suffer due to contraction of demand by Australia's major trading partners. This negative trade effect may reduce activities in sectors such as 'Coal, 'Other metals', 'Other minerals', 'Oil products', and 'Natural gas' more severely than what is reflected by the modest decline of real GDP. Three other sectors that have been adversely affected are 'Electricity', 'Agriculture' and 'Transport services'. These sectors suffer from higher prices of energy and general contraction in domestic demand.

The participation of China and India has a large influence on the global carbon market that has almost halved the permit price in our results. It is important to highlight the impact of these two participants in a global ETS simply because their entrance significantly reduced the GDP loss of all Annex 1 countries. However this gain comes at a loss to China and India since their own real GDP loss becomes substantial as they move from domestic to a global ETS. Our results also confirm that selling permits to the world is not welfare enhancing. Consistent with existing literature (Babiker et al., 2004), results in this paper support the earlier findings that countries who buy permits improve their welfare outcomes from the environment policy because they are able to abate emissions cheaper (See Table 2).

While the results of other Annex1countries are driven by factors similar to that affect Australia, their experience is also dependent on whether they are energy exporters or importers. Hence how trade is affected by the ETS is crucial to them. Japan, being a net importer of energy, has the lowest GDP loss whereas RoA1 countries have the highest due to the unfavourable terms of trade. Nevertheless lower permit price benefits all of them reducing the abatement costs of meeting their respective Kyoto targets.

Three important policy implications we may highlight on the basis of our findings. One, Australia can reduce its abatement cost substantially to meet Kyoto commitment by being a party to an international ETS. However, the government may need to consider policies to assist trade exposed resource exporting sectors in the event of such an agreement is reached in the near future. Use of revenue from permit trading to compensate losers may be a weak strategy in this respect as Australia's major trading partners will demand less energy goods overall since they make their own adjustments towards shifting away from dirty resources. Two, major non-Annex 1 emitters- China and India – can influence world carbon market by driving down the permit price to a low level. However, their willingness to participate in an international ETS at this stage is voluntary and they are not strictly bound by Kyoto protocol. Given that China and India appear to have higher GDP loss by moving into an international carbon market despite projected revenue gains from permit sales, a stronger global agreement may be necessary to make them to take part in an international ETS. Three, buyers of permits in an international carbon markets can gain since they have access to cheaper permits in a global market for carbon. Hence encouraging polluting firms to acquire international permits through a global ETS to meet their abatement targets is an economically efficient environmental policy that needs to be considered seriously.

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Appendix

Table A1: Regional and Commodity Aggregation

Aggregated Region	GTAP Region	Aggregated Commodity	GTAP Commodity
1.Australia (AUS) 2.United States (USA) 3.European Union 27 (EU27) 5.Japan (JPN) 6.Rest of Annex 1 (RoA1) 7.Oil Exporting (EEx) 8.China (CHN) 9.Korea (KOR) 10. India (IND) 11.Rest of World (ROW)	Australia United States EU27 members Japan Rest of Annex 1 Oil Exporting China Korea India All other regions	1.Agriculture, forestry & fishing (AG-F-F) 2.Coal (COAL) 3.Crude oil (OIL) 4.Natural gas (GAS) 5.Other minerals (OMN) 6.Food (FOOD) 7.Textile & leather (TEX) 8.Wood, paper products (WPP) 9.Oil products (OIL-P) 10.Chemical, rubber, plastic (CRP) 11.Mineral products (NMM) 12.Ferrous metals (I-S) 13.Metals nec (NFM) 14.Metal products (FMP) 15.Motor vehicles & parts (MVN) 16.Electronic equipment (ELE) 17.Other manufacturing (OMF) 18.Electricity (ELY) 19.Transport services (TRP) 20.Other services (SER)	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 Coal Oil Gas; gas manufacture and distribution Minerals nec 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 Textiles; wearing apparels; leather products Wood products; paper products, publishing Petroleum, coal products Chemical, rubber, plastic products Mineral products nec Ferrous metals Metals nec Metal products Machinery and equipment nec Electronic equipment Manufactures nec Electricity Transport nec; water transport; air transport 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 8.1 database.