The most advantageous partners for Australia to bilaterally link its emissions trading scheme

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Abstract

The theory of marginal abatement cost (MAC) indicates that if a country has a high MAC, it should link its domestic emissions trading scheme (ETS) with a foreign country which has either low MAC or low emissions reduction target. This is required to maximise its economic benefits from the linkage compared to its domestic ETS. On the other hand, if a country has a low MAC, it would seek a partner which has either a high MAC or a high emissions reduction target. Using a computable general equilibrium (CGE) model, namely the extended GTAP-E model, the authors found that Australia would yield the greatest economic benefits by linking its ETS with India. China is the second best alternative for Australia to link its ETS while the European Union is the most expensive option for Australia. However, any bilateral linkage is always better for Australia than operating its own domestic ETS.

Keywords: Australia, emissions trading scheme, linkage, marginal abatement cost, CGE model.

JEL classification codes: F18, Q56, Q58.

1 Introduction

Since the last decade, many policy makers have been considering an emissions trading scheme (ETS) as a promising policy to tackle climate change issues. There are many schemes currently operating around the world. They include regional ETS in the European Union (EU), national ETSs in Switzerland, Norway, Kazakhstan, New Zealand and South Korea, and many other regional schemes in United States, Canada and Japan (Parliament of

Australia, 2013b). Many researchers have concluded that such schemes not only have moderate effects on economies but also bring great benefits to economic systems (Adams, 2007; Adams et al., 2014; Babiker et al., 2004; Hawkins & Jegou, 2014; Tuerk, 2009). The benefits would be larger if the borders of the schemes are broader. In this regard, several governments have shown their ambition to establish a global emissions trading market because of many advantages from such linkages (European Commission, 2016; Hawkins & Jegou, 2014; Ranson & Stavins, 2015; Siriwardana, 2015). In Australia, the Labor Governments (Rudd 2007-10; Gillard 2010-13; Rudd 2013) had negotiated with the European Union to link the Australian ETS with the EU-ETS after the success in implementing the Carbon Price Mechanism in the domestic market (Deparment of Climate Change and Energy Efficiency, 2012). Under these negotiations, the first stage (2015-18) would be a one-way link where the liable entities in Australia would import allowances from the EU-ETS. From 2018, these two schemes were intended to develop two-way links. In the proposal, the Australian Labor Government also desired to negotiate with other countries in order to link with its ETS (Parliament of Australia, 2013a).

The most significant benefit of the linkage is the opportunity to reduce the total costs of abatements in comparison to operating their own domestic ETSs alone. In a linkage, participants will jointly seek to equalise their marginal abatement costs (MACs) hence the price of permits will converge to an intermediate level. Such an outcome leads to an increase in market liquidity and a decrease in concern for an emissions leakage and unfair competiveness between participants when every firm in the linkage faces the same price for permits (M. Babiker et al., 2004; Flachsland, Marschinski, & Edenhofer, 2009; Hawkins & Jegou, 2014; Jaffe & Stavins, 2008; Siriwardana, 2015; Tuerk, 2009). Using a graphical illustration to show the cost-effectiveness achieved by an international ETS, Babiker et al. (2004) pointed out that two countries in the linkage would equalise their MACs and both economies would achieve net economic gains through the linkage.

In order to carry out such a comparison of benefits, it is assumed that the proposed economies have their own domestic cap-and-trade ETSs and they are compatible in order to unify their domestic ETSs into an international ETS. In each scheme, permits are entirely auctioned. In this paper, the authors will compare the potential economic benefits gained by Australia from a bilateral ETS linkage with the European Union, United States, South Korea, Japan, China and India. We assume the implementations of the schemes in these selected economies could be a promising policy for governments to pursue following the agreements at the 2015 Paris Climate Conference. In addition, if an ETS was implemented in Australia, the first process would likely be the negotiations for bilateral trades with other schemes. In order to complete such comparisons, we use the computable general equilibrium (CGE) modelling approach, namely the extended GTAP-E model. This model particularly suits this task, as it includes complete interactions between consumers and producers throughout the world. Bilateral trades between countries are also presented in the model. In addition, it consists of greenhouse gas emissions in the database, which is released from the production processes and consumption of fuels. Furthermore, the model provides a mechanism to implement ETSs in different economies and a possibility of linking such ETSs.

In this study, the emissions targets for these economies are considered according to their plans for 2030 which they were committed at the 2015 Paris Climate Conference. The analysis focuses assuming that these ETSs are implemented in markets where there are no pre-existing distortions[1]. This is because the problem of "immiserizing growth" occurs when there are pre-existing distortions in partner economies (Bhagwati, 1958; Lipsey & Lancaster, 1956), hence not all countries benefit from a linkage of ETSs (Babiker et al., 2004).

The paper is organised as follows. Section 2 describes the theory of marginal abatement cost in the context of international ETS and a review of previous literature is in Section 3. Section 4 outlines the model, database and emissions targets used in this study. Section 5 presents the simulation results and discussions. Section 6 concludes the paper.

2 Marginal abatement cost

Marginal abatement costs normally differ between countries. In some economies, MAC would increase considerably if they undertake a small amount of additional emissions reduction. However, some other economies would experience only low levels of MAC for every additional unit of abatement. Some of the main reasons for differential MACs between countries are energy efficiency, possibilities of fuel substitutions and sources of emissions. If a country can improve technology in order to use energy more efficiently, their MAC will become lower. In addition, the higher the possibility to substitute clean energy sources (e.g. natural gas) for emissions intensive energy inputs (e.g. coal), the greater the potential for a

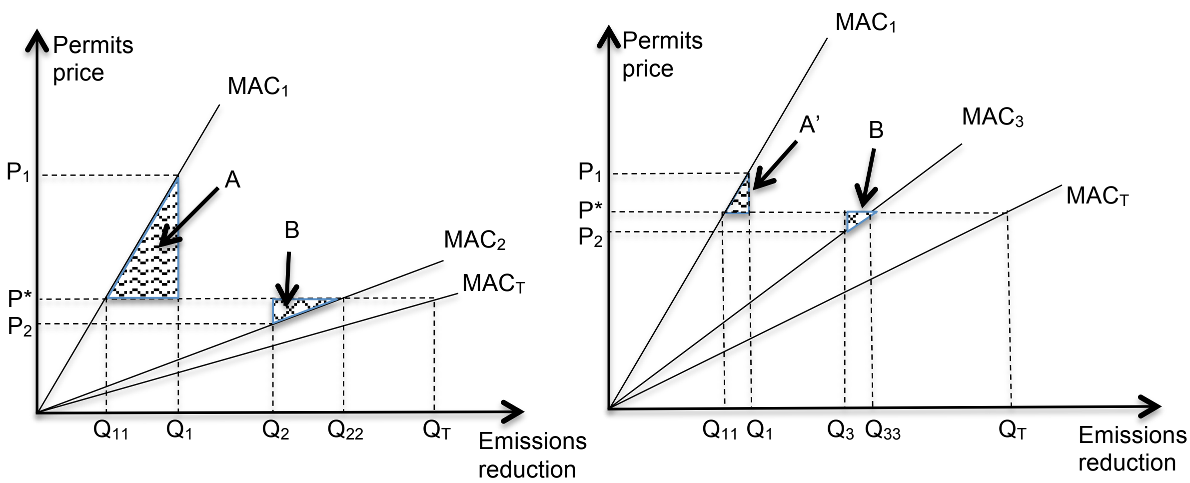
[1] Distortions in a market occur when there are existing taxes, such as taxes on fossil fuels. In addition, such taxes are different from country to country (Babiker et al., 2004).

country to achieve a lower MAC. If a country burns a large amount of fossil fuels in their production processes, a small improvement in technology to switch to clean energy inputs or use of energy more efficiently would enable that country to reduce its MAC considerably. The source of emissions is also an important component to determine the MAC. If a country has a high level of emissions from production processes, it is unlikely that it will have a low MAC as it has to reduce the level of production in order to lower its emissions levels. Labour and capital costs are also major determinants of the MAC level of a country. If such costs are low, it is not costly for the country to reduce its production level, thus diminishing the emissions levels in order to meet a target. Production sectors can also substitute capital for energy when the price of energy increases considerably. As a result, such a country will pay less for every tonne of abatements.

When ETSs are linked together in an international ETS, participants could reduce the total cost of abatements by equalising their MACs. In such a linkage, all countries or regions will achieve economic benefit buts linkage with different partners will yield different benefits to the country. In this regard, Figure 1 graphically shows the cost-effectiveness of an international ETS with two countries.

Figure 1: Cost-effectiveness of an international ETS

(a) (b)



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

Figure 1 (a) indicates that country 1 and country 2 initially perform their domestic ETSs. Country 1 commits to reduce its emissions levels by Q_1 units under its regulation while country 2 reduces its emissions levels by Q_2 units. In addition, country 1 has a relatively high MAC, which is indicated by MAC_1 curve while country 2 has a lower MAC curve, namely MAC_2. Under two independent schemes, country 1 has a higher price of permits than it is for country 2 ($P_1 > P_2$) because country 1 has higher MAC than in country 2. When these two countries link their domestic ETSs, they jointly obtain a lower MAC (indicated by MAC_T) relative to their individual MAC curves. Total emissions reduction units for such a linkage are Q_T (= $Q_1 + Q_2$). As shown in Figure 1 (a), the linkage allows the two countries to obtain an intermediate price for permits (P*). Of these, the high emissions abatement cost country (country 1) will only reduce its emissions by Q_{11} units and buy additional permits (= $Q_1 - Q_{11}$) from country 2. In such a case, country 2 will reduce its emissions by Q_{22} units and sell its surplus permits (= $Q_{22} - Q_2$) to country 1 where $Q_{22} - Q_2$ is equal to $Q_1 - Q_{11}$. As a result, such a linkage enables both country 1 and country 2 to achieve the net economic gains (marked by area A and area B, respectively) compared with their own domestic schemes.

The net gains, area A and area B, however, are subject to change due to a change in partners or emissions targets (or abatement units). For example, if country 2 in Figure 1 (a) reduces its emissions targets or expects to achieve a lower level of emissions reduction units, the total abatement units (Q_T) will decline, hence decreasing the price of permits and increasing the net gain (area A) for country 1. Similarly, if country 2 increases its emissions reduction units, it will reduce net gain for country 1. By contrast, the higher the level of emissions reduction in country 1 the greater the net gains (area B) country 2 will achieve. Figure 1 (b) shows that country 1 links its ETS with country 3, which has the same emissions reduction target as country 2 ($Q_3 = Q_2$) but higher MAC relative to country 2 ($MAC_3 > MAC_2$). With the same analysis as in Figure 1 (a), country 1 only achieves the net gain A', where area A' is smaller than area A in Figure 1 (a). These illustrations suggest that if country 1 is a high MAC country, it should link its domestic ETS with a scheme, which has either a low MAC or a low emissions reduction target, in order to maximise its economic benefits from the linkage compared with its domestic ETS. On the other hand, a low MAC economy like country 2 would seek a partner, which has either a high MAC or a high emissions reduction target.

3 Survey of literature

Studying the effects of the environmental taxes on different economies has been well developed, especially since the use of CGE models for environmental policy analysis. Economists and environmentalists therefore have reliable tools to quantify the comprehensive effects of such policies on various aspects of an economy. Recently, there has emerged a wide range of empirical literature that develops applications of CGE modelling in order to estimate the effects of ETSs. Many studies have focused on the European Union ETS (EU-ETS) subject to the Kyoto Protocol commitment. For example, Böhringer (2002) used a world CGE model to examine the effects of the restricted levels for trading emissions on the magnitude and distribution of abatement costs across EU countries. The model encompasses 7 sectors and 23 regions, including 15 EU member states. The database for the model was constructed from four sources with a base year of 1995. Of these, GTAP4 contains global Input-Output tables; EUROSTAT includes Input-Output tables for all EU member countries; IEA provides energy balances and energy prices/taxes; and CHELEM supplies harmonized accounts on bilateral trade between countries. The author found that allowing for the possibility of trading between power sectors across country borders would provide the highest efficiency gains, instead of restricting them to domestic markets subject to the electricity sectors receiving permits at an auction price, rather than free.

Babiker et al. (2003) used the Emissions Prediction and Policy Analysis European Union (EPPA-EU) model in order to examine (1) how the allocation of emissions permits between sectors affect the welfare costs in the European Union and (2) the effects of the climate change strategy on domestic production. Such a model is a global dynamic general equilibrium model, which includes 11 sectors and 22 regions. The simulation results indicated that permit allocations would lower economic costs if such allocations differ from the trading solution in the simulations while the European economy would bear more costs in the case of exempting energy-intensive industries. The findings also suggest that divergence from the domestic economy-wide cap-and-trade system increases economic costs but the EU economy is better off rather than having an economy-wide cap-and-trade system due to existing energy taxes in the various economies.

Kemfert et al. (2006) used the GTAP-E model in order to analyse the abatement costs and welfare impacts of the EU-ETS. The GTAP-E model is a static multi-country and multi-sector CGE model. There are three scenarios in this study. In Scenario 1, the emissions quota for each selected sector of each region was fixed, the carbon prices were then determined endogenously. There was no trading of emissions in this scenario. Scenario 2 allowed emissions trading between sectors within each country’s border. In Scenario 3, all selected sectors could trade their permits within the EU region. The permit allocations were based on the national allocation plans[2] as submitted to and approved by the EU. The simulation results show that the real GDP increased in all regions while welfare gains mostly occurred in regions where high efficiency gains from emissions trading were experienced. When emissions permits were allowed to trade across the borders, the abatement costs for all EU States members were relatively low (at US$2 per tonne of CO_2). In such a trading scenario, Germany, UK and the Czech Republic were the main sellers of emissions permits, whereas Belgium, Denmark, Finland and Sweden became the main buyers.

Edwards and Hutton (2001) applied a CGE model in order to compare the economic effects of different methods of permits allocation within the UK, subject to a target (i.e. reducing the UK's emissions level by 17.5% relative to business-as-usual). This CGE model consists of 12 perfectly competitive sectors, nine being fuels and three non-energy. The authors assumed that the permits were traded internally in the UK market. The main findings included (1) if revenue from permit auction is recycled to industry through output subsidies or employment tax cuts, it is likely to cause a 'double dividend'. (2) When permits are allocated freely, the cost is increased if foreign-owned companies consider such permits as a windfall to repatriate to shareholders. However, in the case of free allocation using benchmarks, it is not necessarily costly. (3) The 2010 UK's emissions target needed much tighter controls beyond 2010, especially as a rapid growth in carbon use outside the Organisation for Economic Co-operation and Development area was expected. In that case, the authors suggested that taxes and permit prices could be much higher than the price levels found in the study.

Kim et al. (2004) used a CGE model to evaluate the effects of the dual system of carbon tax and ETS on South Korea's economy. Such a model is a multi-sector recursive dynamic CGE model, which includes 21 goods and services. The ETS was applied for large emitters while a carbon tax was applied for small emitters. Two cases of emissions reduction were considered in this study. They are a 20% reduction target scenario and 1995 emissions level stabilization scenario. The results show that the targets could be achieved in both scenarios via the dual system. In addition, MACs of large emitters would increase faster than those for small emitters in South Korea. The authors concluded that the carbon tax along with an ETS would be the most efficient option for South Korea to reduce emissions if the carbon tax and the price of permits were applied to emitters according to their levels of marginal cost.

[2] A national allocation plan determines how many allowances to be allocated in total and to each EU ETS installation on their territory.

There were also many studies, which applied the CGE models to assess the effects of an ETS on the Australian economy. The ETS was either applied in the domestic market only or as a part of the global or international emissions trading market. For example, Adams (2007) used the Monash Multi-Regional Forecasting (MMRF) model with key inputs related to the electricity sector supplied by McLennan, Magasanik Associates (MMA) in order to evaluate the likely costs of an ETS on the Australian economy. The MMRF model is a dynamic model, containing 52 industries, 56 commodities, 8 states/territories and 56 sub-state regions of Australia. Of these, the outputs of the MMA model were the inputs in the MMRF model. Adams suggested that the ETS should be introduced in Australia, as the economy would grow strongly in the case of ETS. Adams also indicated that the compensation for energy cost increases could allow maintenance of global trade competitiveness for Australian producers. In addition, the impacts on economic welfare could be moderated via targeted recycling of revenue from auctioned permits.

Gerardi and Demaria (2008) quantified the impacts of the Carbon Pollution Reduction Scheme (CPRS) on the Australia's electricity generation sectors by using an integrated CGE modelling approach. Such an approach includes a suite of models, such as the GTEM model (outlined the international impacts), the MMRF model (detailed the domestic impacts) and the MMA's electricity market models (presented the sectoral impacts). In this approach, outputs of the other modelling simulations were key inputs into the electricity market simulations. The simulation results indicate that the emissions levels of the Australian electricity sectors in all policy scenarios were far lower than the emissions level projected in the baseline. They also found that there was a strong transition to renewable energy industries in Australia. Such renewable energy production was predicted to contribute half of the generation mix by 2050.

Hoque et al. (2010) used the MMRF-Green model in order to assess the impacts of the CPRS-5[3] on the Australian economy, particularly the tourism sectors. As the tourism sector is not disaggregated in the database, the authors obtained the effects on the Australian tourism industry by linking the MMRF-Green model and Tourism Satellite Account (TSA)[4] methodology. That is, the authors had to map the industry in the TSA and MMRF-Green

[3] The CPRS is an emissions trading scheme for GHG emissions, which the Australian government proposed to commence in 2011. The CPRS-5 scenario indicates that a cap on the Australian emissions is set at 475 Mt in 2020, that is 5% below the 2000 level (of 500 Mt) by 2020.

[4] A TSA provides macroeconomic aggregates that describe the size and the economic contribution of tourism output, tourism direct gross value added and tourism direct gross domestic product, consistent with similar aggregates for the total economy, and for other productive economic activities.

model industry. In the modelling, an initial price of emissions of A$25 per tonne was imposed in 2011 and the Australian industries could buy emissions permits from the international markets in order to meet their national obligations. The projections were obtained until 2020. As a result, Australia only experiences a mild contraction in the economy at the macro level compared with the baseline scenario. Most tourism industries would only experience small contractions in their real outputs and some industries would undergo expansion. Among them, the most adversely affected industries were cafes, restaurants and food outlets, air transport, and water transport with reductions in outputs by 1.32%, 1.32% and 0.82%, respectively. The most favourably affected sector was rail transport with an expansion in activity by 1.28%, as it is a low emissions intensive industry.

In 2011, the Australian Treasury (2011) released a comprehensive analysis of the carbon pricing in Australia by using the CGE modelling approach. The analysis was based on the simulation results from a combination of many models, such as two top-down dynamic CGE models (the GTEM and MMRF models); bottom-up sector-specific models for electricity generation and road transport sectors; a partial-equilibrium model of the Australian energy sector (the Energy Sector model); the model for estimating the impact of the Carbon Farming Initiative on the Australian forestry sector; the Treasury's Price Revenue Incidence Simulation model (to quantify the effects of a carbon price on a range of prices); and the Treasury's Price Revenue Incidence Simulation model and Distribution model (to analyse the distributional implication for households). In Scenario 1, carbon price was assumed to start from A$20 per tonne in 2012-13, rising 5% per year, projected to be around A$29 in 2015-16. In Scenario 2, the starting carbon price in 2012-13 was assumed to be at A$30 per tonne, rising to A$61 in 2015-16. In both modelling scenario results, the real income of Australia still grew but at a slightly diminishing rate, as the domestic economy transforms to be more carbon efficient and as sourcing international abatement causes income outflow. Pricing carbon affected the demand for labour as a result of slower output and capital growth, however, the level of employment was unaffected. Labour moved across industries during the transition to a lower carbon economy, although the rate of movement was relative low compared to normal rates of job turnover from year to year. In this study, pricing carbon would considerably change the composition of electricity generation in Australia. Electricity generation from renewable sources was estimated to be higher in both scenarios. Renewable generation would rise by 20% and 21-26% of total electricity generation output by 2020 under Scenario 1 and Scenario 2, respectively. Wind generation would develop quickly initially, then it would be overtaken by geothermal energy generation. The results also indicated that gas would play an important role in generating electricity in Australia in both scenarios.

Adams et al. (2014) investigated the effects of an ETS on the Australian electricity sector. The ETS in Australia was a part of the global ETS. Hence, the dynamic multi-country CGE model, namely the GTEM model was used to generate the prices and allocations of permits for Australia. The outputs were then the inputs in the MMRF model. In addition, the electricity sector in MMRF was replaced by the WHIRLYGIG's specification. The WHIRLYGIG model includes detailed information of the Australian electricity sectors, including wholesale and retail electricity prices, capacity by generation type, fuel use, emissions, etc. The main findings were that the global price of permits increased from A$25 per tonne in 2015 to A$50 in 2030, Australia would need to buy half of its abatement required from overseas markets and Australia would only experience a reduction in GDP by 1.1% in 2030 relative to the baseline.

Siriwardana (2015) used the GTAP-E model in order to assess the effects of ETSs linkage between Australia, Japan and South Korea on their economies and emissions levels. The linkage was carried out as a complement to the free trade agreements (FTAs) between Australia and the other two countries. The GTAP-E model is a static multi-region and multi-sector CGE model. Two scenarios were examined in his study. In Scenario 1, the simulation was performed by cutting all bilateral tariffs between Australia and the other two countries. Scenario 2 was carried out with an additional ETSs linkage between these three economies. The emissions quota or target for each of the three countries followed the 2020 targets, ratified at the Cancun conference in 2010. Such 2020 targets were then converted into targets in the base year 2007. The author found that removing bilateral protection of trade brings significant benefits to all three countries. Real GDP and welfare in these three countries were likely to increase. However, when the FTAs were under operation with the complement of the ETSs, real GDP of these three countries were reduced considerably (e.g. -3.69% for Australia, -2.43% for Japan and -3.52% for South Korea). The price of permits was also very high. Based on such findings, the author indicated that an ETS linkage between Australia, Japan and South Korea would be a very expensive option, as all three countries would lose their competitive advantage.

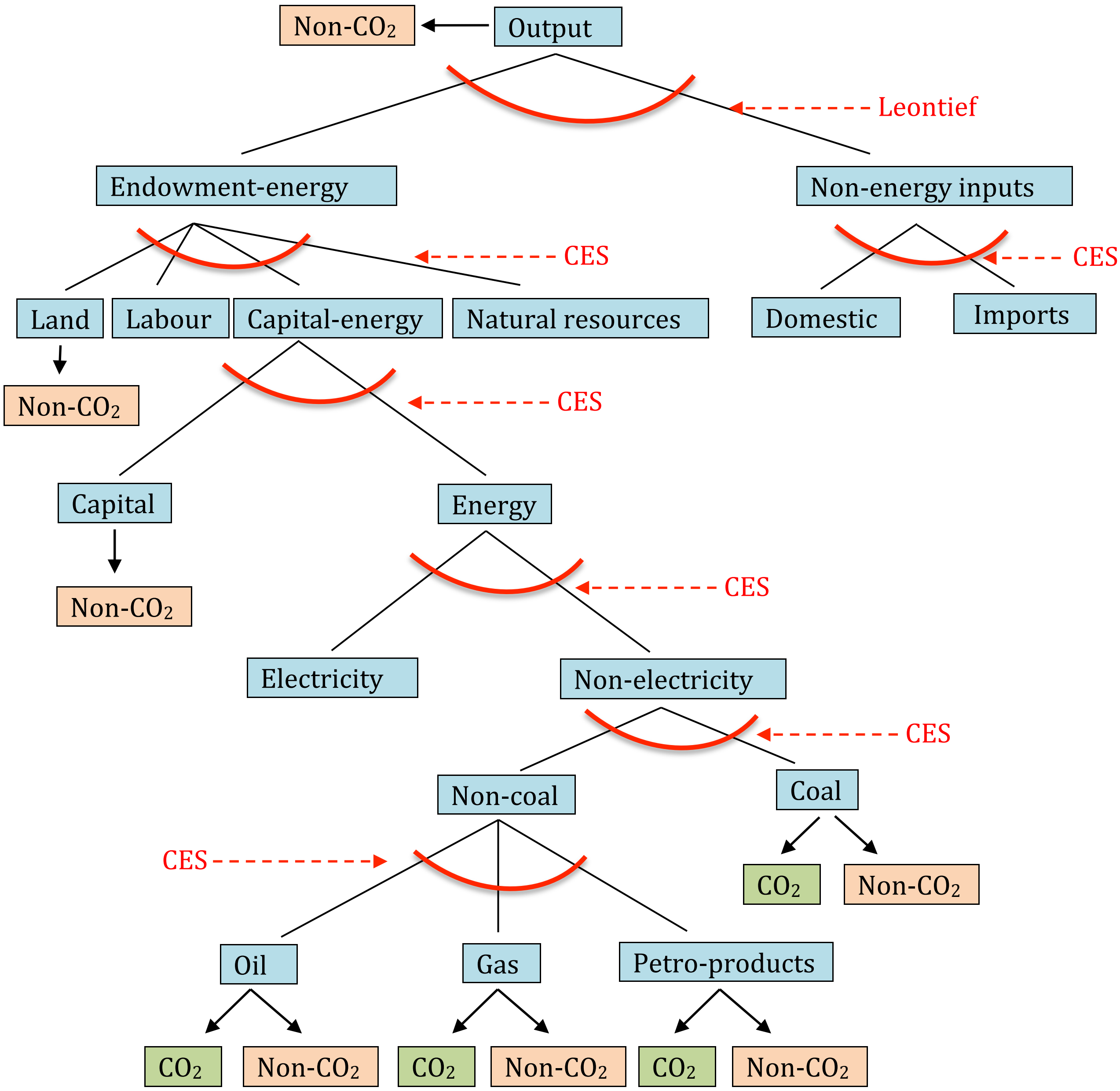
4 Model and database

4.1 Model structure and database

This study uses an extended GTAP-E model in order to quantify the net economic gains for Australia from different bilateral ETS linkages. In GTAP-E, consumers are modelled to maximise utility, while firms or producers will try to minimise costs. The model also contains market-clearing conditions, where supplies of goods and services are equal to demands. In addition, the model displays flows of bilateral trade of goods and services between countries.

In this extended version of the model, we retain the production and demand structures of the original GTAP-E model. As outlined in Figure 2, the production structure is a combination of five levels of constant elasticity of substitution (CES) production functions and one Leontief function. At each level of CES, industries can substitute cheap inputs for relatively expensive inputs, depending on the magnitudes of the substitution possibilities. For example, at the bottom level, the CES function allows industries to substitute gas or petroleum products for oil when oil becomes more expensive relative to gas or petroleum products. Such a selection creates a non-coal commodity composite for selection in the next level of CES function. In the next level, the CES function provides the same procedure to select between coal and non-coal composites subject to their prices. As a result, each firm or industry will minimise their input costs through the CES functions according to their existing substitution possibilities. At the highest level, industries select the input combination between endowment-energy composites and non-energy composites through the Leontief function, which does not allow them to substitute between these two inputs.

Figure 2: The production structure in GTAP-E model



Sources: Adapted from McDougall and Golub (2007) with enhancements by the authors.

The enhancements also include incorporation of non-CO_2 emissions in the database in addition to the original CO_2 emissions. The variables and equations related to such non-CO_2 emissions were also developed in the modelling in the same way as in CO_2 emissions. Such modifications to emissions allow the capture of comprehensive emissions levels in each region, hence the analysis of climate change policies would be more accurate, complete and efficient. In augmenting the emissions database, it was assumed that the non-CO_2 emissions intensities for domestic and imported consumptions are the same, thus such emissions from domestic and imported consumptions by firms and households were allocated according to the imported and domestic consumption values by these agents. The incorporation of non-CO_2 emissions results in emissions from endowment usage and production activity, while the original CO_2 emissions in the model are only from fuel combustions. As shown in Figure 2, non-CO_2 emissions also come from combustion of oil, gas, petroleum products and coal. In addition, non-CO_2 emissions come from the use of land and capital in the agricultural sector. The non-CO_2 emissions are also released in production processes, shown as emissions from the output production process in Figure 2, and by the use of 'chemical, rubber and plastic products', and 'gas manufacture and distribution' commodities.

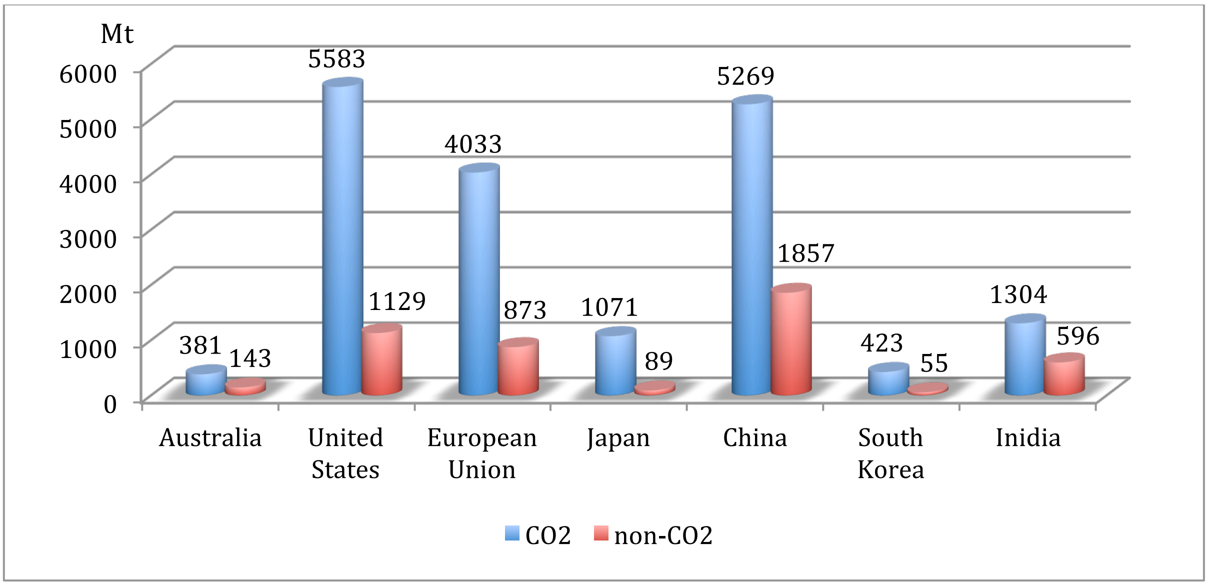
Table 1: CO_2 and non-CO_2 emissions by sectors, government and household consumptions in the selected regions (million tonnes (Mt).

	Australia		United States		European Union		Japan		China		South Korea		India	
	CO_2	Non-CO_2	CO_2	Non-CO_2	CO_2	Non-CO_2	CO_2	Non-CO_2	CO_2	Non-CO_2	CO_2	Non-CO_2	CO_2	Non-CO_2
Agriculture	**5.66**	**91.9**	**48.2**	**489.32**	**60.1**	**469.44**	**10.78**	**33.21**	**106.3**	**1205.2**	**6.21**	**15.71**	**21.01**	**402.97**
from endowment usage	0	79.34	0	214.03	0	281.28	0	24.17	0	605.21	0	13.44	0	355.95
from production processes	0	0.52	0	1.44	0	2.48	0	0.15	0	0	0	0.53	0	0.84
from fuel combustions	5.66	12.04	48.2	273.85	60.1	185.68	10.78	8.89	106.3	599.99	6.21	1.74	21.01	46.18
Coal mining	**2.5**	**22.7**	**1.65**	**56.08**	**1.35**	**36.99**	**0**	**0.3**	**105.41**	**231.84**	**0.05**	**0.89**	**0.97**	**22.36**
Oil extraction	**1.41**	**0.37**	**23.25**	**22.47**	**7.64**	**1.24**	**0**	**0.05**	**33.29**	**1.12**	**0.13**	**0.01**	**6.03**	**0.98**
Gas extraction	**3.41**	**3.65**	**65.91**	**72.45**	**19.35**	**26.19**	**0.27**	**0.25**	**26.96**	**0.34**	**0.93**	**0.01**	**11.17**	**0.52**
Oil products manufacturing	**12.56**	**0.48**	**181.47**	**5.91**	**129.91**	**17.33**	**29.58**	**0.82**	**78.73**	**12.86**	**15.72**	**3.15**	**36.53**	**8.66**
Electricity generation	**212.04**	**0.72**	**2413.94**	**20.7**	**1340.1**	**11.36**	**442.85**	**0.95**	**2957.41**	**18.77**	**193.7**	**1.8**	**770.71**	**2.54**
Other manufacturing	**40.58**	**6.17**	**447.17**	**186.17**	**434.26**	**126.25**	**166.11**	**42.73**	**1124.16**	**182.73**	**56.16**	**13.45**	**198.41**	**15.94**
Transportation	**63.18**	**4.87**	**1168.03**	**76.5**	**1120.25**	**37.84**	**177.4**	**5.86**	**320.33**	**4.74**	**77.1**	**2.45**	**99.32**	**11.93**
Other services	**5.6**	**11.62**	**215.48**	**195.03**	**194.7**	**131.01**	**103.72**	**4.84**	**169.22**	**196.66**	**21.64**	**17.72**	**46.91**	**130.35**
Government consumption	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.01**	**0**
Household consumption	**34.24**	**0.6**	**1018.18**	**4.24**	**725.74**	**15.2**	**140.72**	**0.1**	**346.83**	**3.07**	**51.24**	**0.28**	**112.7**	**0.2**
Total	**381.18**	**143.08**	**5583.28**	**1128.87**	**4033.4**	**872.85**	**1071.43**	**89.11**	**5268.64**	**1857.33**	**422.88**	**55.47**	**1303.77**	**596.45**

Source: GTAP-E database (base year 2007).

Table 1 shows the data in the new database related to CO_2 and non-CO_2 emissions from industrial sectors, government and household consumptions in the selected regions. The addition of non-CO_2 emissions significantly improves the quality of the database. The agricultural and coal mining sectors considerably increase their emissions levels across the regions when non-CO_2 emissions are incorporated in the database because data further represents emissions from endowment usages and fugitive activities. Other manufacturing and other services sectors also show significant increases in their emissions levels in all regions due to incorporation of non-CO_2 emissions mainly from production processes. The incorporation of non-CO_2 emissions, however, does not considerably alter emissions levels of household and government consumptions.

Figure 3: CO_2 and non-CO_2 emissions levels by country (Mt).



Source: GTAP-E database (base year 2007).

Figure 3 compares CO_2 and non-CO_2 emissions levels in different regions in the new database. If the database only includes CO_2 emissions, Australia, for example, only releases 381Mt of emissions. When there is a presence of non-CO_2 emissions, the Australia's emissions level increases significantly by 38% (=((381+143) – 381)/381 – 1) to 524Mt (=381 + 143). It is much closer to the 2007 level of emissions reported by the Australia Department of the Environment, that is 575Mt (Department of Climate Change, 2013). Similarly, new emissions of the United States, European Union, Japan, China, South Korea and India also increase by 20%, 22%, 8%, 35%, 13% and 46%, respectively.

In the modelling, the authors also separate non-CO_2 and CO_2 emissions variables in order to assess the fluctuation of CO_2 and non-CO_2 emissions. In the case of emissions trading, total emissions (the sum of CO_2 and non-CO_2 emissions) will be traded together but the fluctuation of CO_2 and non-CO_2 emissions by each agent will be reported separately, along with the fluctuation of total emissions. This flexibility allows us to focus on the type of emissions for a particular sector. For example, environmentalists would need to know the fluctuations of NO_2 and CH_4 emissions in agricultural sectors.

The extension of the model also includes development of coding in order to flexibly evaluate the effects of climate change policies. For example, a carbon tax can be imposed in selected sectors in a particular region. An ETS can also be implemented in a domestic region with selected sectors. In a linkage, the selected sectors can trade their permits across the borders while other sectors will not participate in the emissions trading market or will not need to buy permits to cover their emissions.

4.2 Emissions permit allocation

At the 2015 Paris Climate Conference, many countries and regions have agreed to reduce their emissions levels by 2030. Of these, three levels of emissions targets have been estimated: sufficiency, medium and inadequacy. The estimates suggest that none of the selected countries and regions in this study has sufficient abatements (Arup, 2015). China, the European Union and India only have high levels of abatements, which are close to the sufficient levels. The emissions target of the United States is on the medium level but it is very close to the inadequate level. The remaining countries, Australia, Japan and South Korea, have the targets belonging to the third rank, which indicate inadequate efforts to reduce emissions.

These 2030 emissions targets relative to the base year levels are presented on the third column of Table 1 (Arup, 2015). China and India have committed to reduce their emissions intensities of GDP by 2030 relative to 2005 levels; hence their 2030 emissions targets relative to the 2005 levels are calculated as follows:

$$\frac{CO2\_e_{2030}}{GDP_{2030}} = (1 - \text{emission intensity reduction})* \frac{CO2\_e_{2005}}{GDP_{2005}}$$

$$\Leftrightarrow CO2\_e_{2030} = (1 - \text{emission intensity reduction})* \frac{GDP_{2030}*CO2\_e_{2005}}{GDP_{2005}}$$

The GDP_{2005} of China and India are taken from the World Bank (2014a). This study assumed that GDP of China in 2030 could be based on its annual GDP growth rate in 2005 (World Bank, 2014b), while GDP of India in 2030 is forecasted by the World Bank (2014c). Emissions of China and India in 2005 are taken from UNFCCC (2014). Based on the emissions data published by the World Bank for the period 2000-2010, the emissions growth rate for South Korea was used in order to calculate emissions target by 2030 relative to its business-as-usual emission levels.

As the GTAP-E model is a static CGE model, which can only present the effects of a policy change at one period, and emissions levels in the database is in the base year 2007, we revert these emissions targets to the targets in 2007 (see the fourth column in Table 1). Such reversions are based on the average emissions growth rates in each economy from 2000 to 2010[5].

These emissions targets for a whole country are equally imposed on each sector of the corresponding economy, hence emissions permits allocated to each sector within an economy are proportional to their emissions levels. For example, Australia has to reduce its national emissions levels by 34% relative to the 2007 level, hence each sector in Australia must reduce their emissions level by 34%. Consequently, permits allocation to each sector in Australia equals to 66% (=1 - 34%) of its emissions level.

Table 2: Emissions reductions from the 2007 levels

Base year	Region	2030 emissions targets relative to base year	Required Change in CO_2e from the 2007 levels
2005	Australia	-28%	-34%
2030	South Korea	-37%**	-30%
2005	China	-60%*	-25%
1990	European Union	-40%	-17%
2005	United States	-28%***	-18%
2013	Japan	-26%	-6%
2005	India	-35%*	-17%

*Note: * refers to a reduction of CO_2e emissions per unit of its GDP relative to base year. ** indicates a reduction relative to business-as-usual. *** The United States submitted its emissions target by 2025.*

Sources: From commitments at the 2015 Paris Climate Conference (Arup, 2015) and calculations by the authors.

[5] In order to get emissions in the same period 2000-2010, emissions for Australia, Japan, the United States and the European Union are collected from UNFCCC, while emissions in this period for China, South Korea and India are gathered from the World Bank.

5 Simulation results

The ETS places a cost on the economy, as it requires firms to pay for their emissions. The abatement costs would be low if firms use energy more efficiently by updating to a new technology or buying new machines. In addition, a country can have low abatement costs if it has better prospects to substitute for dirty energy inputs. Linking with another scheme is also a valuable option to reduce its abatement costs.

Table 3 shows some key macroeconomic effects on the Australian economy of its domestic ETS and different bilateral ETS linkages with South Korea, China, the European Union, United States, Japan and India. The simulation results clearly indicate that every bilateral ETS linkage between Australia and its partner yields better outcomes for Australia than from its domestic ETS. For example, if Australia has its own domestic ETS, the price of emissions permits is US$54.7 per tonne of CO_2e, which is much higher than the permit prices in the case of linking its ETS with other schemes. Real GDP and other macroeconomic effects are also unfavourable if Australia operates the ETS on its domestic market only. Such findings suggest that Australia has a high MAC relative to other selected economies. By bilaterally linking its ETS with any selected scheme, Australia can reduce the cost burdens on its economy, thus moderating the economic effects.

Table 3: Macroeconomic effects on the Australian economy of different bilateral ETS linkages (percentage changes)

Australian Index	Bilateral ETS linking with						Domestic ETS
	South Korea	China	European Union	United States	Japan	India	
Price of permits (US$)	$33.20	$18.30	$36.80	$26.40	$24.40	$11.20	$54.70
Emissions trading (Mt CO_2e)	-41.68	-84.35	-34.06	-60.2	-63.97	-110.62	0
Expected net rate of return	-0.69	-0.32	-0.7	-0.47	-0.57	-0.18	-1.1
Capital stock (end of period)	-6.97	-4.16	-7.54	-5.64	-5.57	-2.57	-10.1
Real GDP	-2.93	-1.71	-3.18	-2.34	-2.31	-1.03	-4.36
Consumer price index (CPI)	0.55	0.45	0.76	0.65	0.5	0.29	1.18
Real household income	-2.02	-1.28	-2.17	-1.64	-1.7	-0.76	-2.69
Real Household consumption	-2.01	-1.27	-2.16	-1.64	-1.69	-0.75	-2.68
Welfare (in terms of equivalent variation) (US$ million)	-19,377	-12,186	-20,939	-15,844	-16,045	-7,317	-26,342

Source: Model simulations.

As shown in Table 3, linking with India yields the lowest price per permit (US$11.2 per tonne of CO_2e), followed by linking with China (US$18.3). The highest price of permits is in the international linkage between Australia and the European Union (US$36.8). In addition, in these linkages Australia always becomes a permit buyer. The largest volume of permits imported by Australia is from the linkage with India. It is consistent with the theory of MAC in Figure 1 (a) because Australia has a higher MAC compared to the MACs of the other economies; hence at the lower price of permits Australia will import emissions permits. Such theory also indicates that linking with India's ETS provides the greatest net economic gain for Australia. In fact, the simulation results show that linking with India's scheme yields modest effects on the Australian economy relative to the results from other bilateral linkages. Every macroeconomic outcome shown in Table 3 in the linkage between Australia's and India's ETSs yields lower rates compared with those in other bilateral linkages. For example, by linking with India's ETS, real GDP in Australia reduces by 1.03%. The consumer price index only increases by 0.29%. Real household income and consumption reduce by 0.76% and 0.75%, respectively. In addition, Australia's economic welfare measured by equivalent variation reduces by US$7,317 million while its economic welfare would decline by US$20,939 million in the case of linking with the European Union's ETS or US$26,342 million if Australia operates its own domestic ETS.

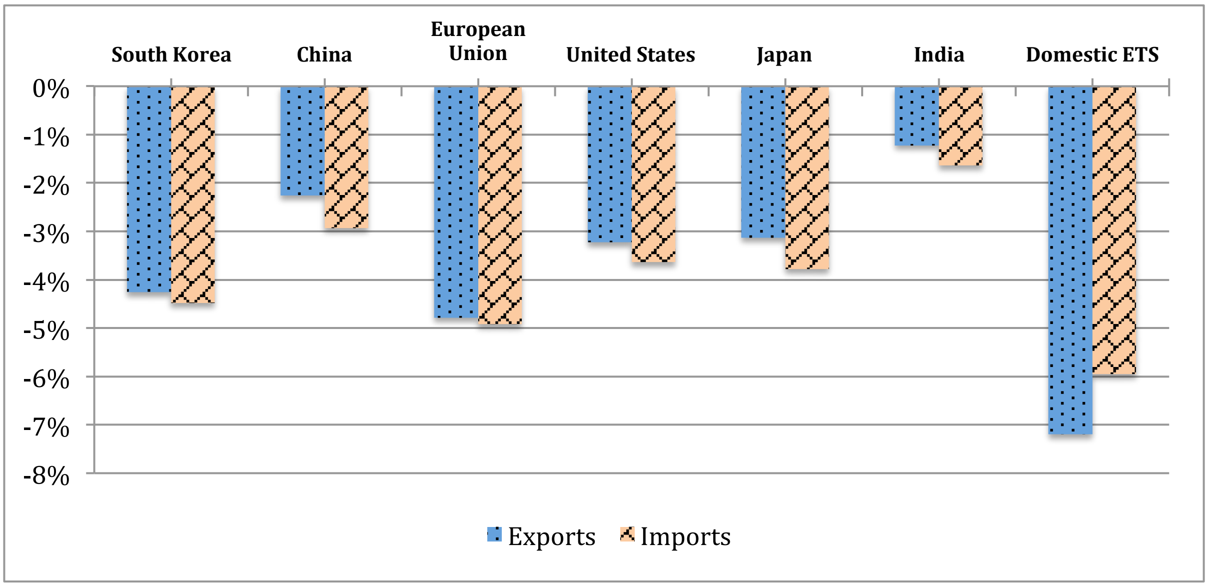
In the ETS simulation, the carbon price puts a cost on emissions, thus considerably increasing production costs. The carbon price also increases the cost of investment, subsequently reducing expected net rate of return and investment in capital stock. In the demand side, the ETS increases the overall price level indicated by the consumer price index (see Table 3). It particularly leads to increases in the price of fuels, the price of electricity and the prices of goods, which are produced with energy-intensive inputs. Hence, real private consumption will fall. Such effects on the economy lead to a decline in real GDP.

Real household income will also decline due to reductions in the factor prices, such as wage rates. The reductions in real household consumption and income are the same throughout the linkages, as we have fixed expenditure share in private incomes.

Figure 4 indicates Australia's export and import volumes which will result from linking with different schemes and its own domestic ETS. In all cases, Australia's exports and imports are reduced. When the ETS results in the contraction of the Australian economy, it will lower demand for inputs, thus reducing its imports. At the same time, the ETSs are also implemented in the other economies and present unfavourable effects on their production and economies; they will also lower their demands. In this study, the selected economies are the biggest importers for Australia's commodities[6], hence the reductions in their demand for inputs would considerably affect the exports from Australia. As a result, Australia's exports will fall.

Similar to other macroeconomic findings, if Australia implemented its own domestic ETS, the effects on their exports and imports would be worst relative to linking with any other schemes. Linking with India's scheme is still the best option for Australia in order to lower unfavourable effects on its exports and imports. In the linkage with India's scheme, Australia's exports and imports only reduce by 1.22% and 1.64%, respectively.

Figure 4: Australia' export and import volumes from bilateral ETS linkages and its own domestic ETS



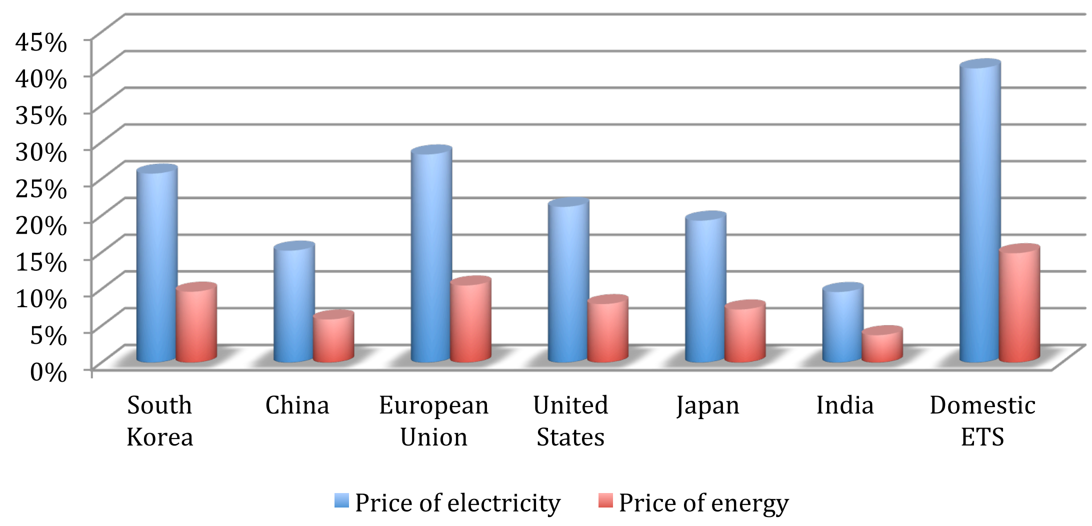
Source: Model simulations.

Figure 5 outlines the prices of electricity and energy in Australia under different scenarios. In Australia, electricity generation mainly relies on fossil fuels, hence the carbon price significantly increases the outlay of such a sector, eventually increasing the price of electricity. The costs of the ETS on the emissions considerably affect the energy sectors, thus reducing their supplies. In the demand side, although demands for energy by other sectors are reduced, it would not be adequate to compensate the reductions in the supply of energy. In

[6] In the database, total export value at market prices from Australia to these six economies accounts for 68% of total Australia' exports.

addition, an increase in the electricity price also constitutes of an increase in the price of energy. Taken together, the price of energy subsequently declines. The price of electricity is particularly high (an increase of 40%) when Australia does not link its ETS with other schemes. In the case of linking ETSs, the highest increasing rate in the electricity price in Australia is only at 28.32% with a link with EU-ETS, while its price of electricity only increases by 9.6% in the case of linking with India's scheme.

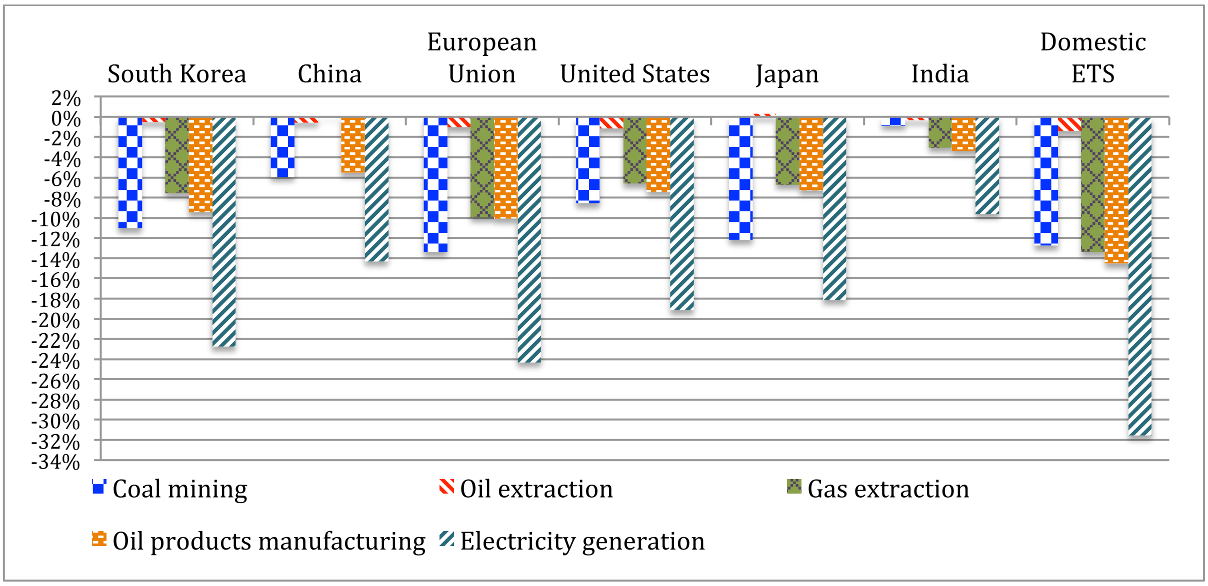
Figure 5: Prices of electricity and energy in Australia in different scenarios



Source: Model simulations.

In Figure 6, we provide the effects of the ETSs on the production levels of the energy sectors in Australia. The Australian electricity generation sector experiences the highest reduction in its production level because it is the highest emissions intensive sector. Another negative effect on the electricity generation sector is the reduction in electricity demand because of considerable increases in the price of electricity. Production level reductions in coal, gas and oil products manufacturing sectors are due to considerable reductions in demands from other sectors and final users, as they are high emissions intensive inputs. Overall reductions in exports also reduce demands for these energy commodities. In addition, such sectors also bear the costs on their fugitive emissions.

Figure 6: Effects of ETSs on production levels of the Australian energy sector in each scenario



Source: Model simulations.

Our findings indicate that subject to the 2030 emissions targets, Australia has the highest MAC (indicated by the price for permits in Table 3), followed by the European Union, South Korea, United States, Japan, China and India. China and India have very low MACs compared to other economies as they have low costs of labour and capital than those other selected economies. On the other hand, developed countries normally have high costs of labour and capital, hence for every unit of additional emissions abated, such countries have to pay relatively higher MACs. As a result, Australia could obtain the optimal net economic gain by linking its ETS with India. China would be the second choice for Australia to seek for co-operation in trading emissions. Linking with the European Union or South Korea is a very costly option for Australia but it is still better than operating its own domestic ETS. The findings also suggest that the price levels for permits significantly affect the economies. The higher the price for permits the higher level of unfavourable effects the country has to face.

6 Conclusions

This paper explores the theory of marginal abatement cost in the case of linking two domestic ETSs. The purpose behind this is to examine which conditions are critical to obtaining net economic gain for a country. The findings suggest that if a country has a high MAC, it should link its domestic ETS with a scheme which has either low MAC or a low emissions reduction target, in order to maximise its economic benefits from the linkage compared with its domestic ETS. On the other hand, if a country has a low MAC, it would seek a partner, which has either high MAC or a high emissions reduction target.

By using the extended GTAP-E model, we can find which economies among the European Union, United States, China, Japan, South Korea and India, are the most advantageous partners for Australia with which to bilaterally link its ETS. The findings suggest that subject to the 2030 emissions targets, Australia has a high MAC while India has the lowest MAC relative to those for other economies, hence linking ETSs between Australia and India would yield the highest economic benefits to Australia. China is the second best choice for Australia to link its ETS, while the most expensive option for Australia is the linkage with the European Union. However the theoretical framework and simulation results have shown that linking with any other scheme would always yield better outcomes for Australia than having its own domestic scheme.

In reality, there are only a few ETSs currently under operation around the world. It is therefore very challenging for a country to seek an appropriate partner with which to link its ETS. In addition, country A may be the best partner for country B but country B would not necessarily be the best partner for country A. However our findings suggest that when there are many ETSs and each scheme looks for a partner, they will eventually lead to a global ETS. Consequently, all economies in the linkages are better off as the more schemes in the linkage, the lower total costs of abatements they would achieve.

References

Adams, P. D. (2007). Insurance against catastrophic climate change: how much will an emissions trading scheme cost Australia? *Australian Economic Review, 40*(4), 432-460.

Adams, P. D., Parmenter, B. R., & Verikios, G. (2014). An Emissions Trading Scheme for Australia: National and Regional Impacts. *Economic Record, 90*(290), 316-344.

Arup, T. (2015). Paris UN climate conference 2015: Australia ranked third to last for emissions. *The Sydney Morning Herald*. Retrieved from http://www.smh.com.au/environment/un-climate-conference/paris-un-climate-conference-2015-australia-ranked-third-to-last-for-emissions-20151207-glhtxf.html

Australian Treasury. (2011). Strong growth, low pollution: modelling a carbon price. *Australian Government, Canberra*.

Babiker, M., Reilly, J., & Viguier, L. (2004). Is international emissions trading always beneficial? *The Energy Journal*, 33-56.

Babiker, M. H., Criqui, P., Ellerman, A. D., Reilly, J. M., & Viguier, L. L. (2003). Assessing the impact of carbon tax differentiation in the European Union. *Environmental Modeling & Assessment, 8*(3), 187-197.

Bhagwati, J. (1958). Immiserizing growth: a geometrical note. *The Review of Economic Studies, 25*(3), 201-205.

Böhringer, C. (2002). Industry-level emission trading between power producers in the EU. *Applied Economics, 34*(4), 523-533.

Deparment of Climate Change and Energy Efficiency. (2012). *Interim partial (one-way) link between the Australian emissions trading scheme and the European Union emissions trading scheme*. Retrieved from https://ris.govspace.gov.au/.../04-Linking-EU-ETS-RIS-for-Publishing-20120830.doc.

Department of Climate Change. (2013). *National Greenhouse Gas Inventory - Kyoto Protocol classifications*. Retrieved from http://ageis.climatechange.gov.au/.

Edwards, T. H., & Hutton, J. P. (2001). Allocation of carbon permits within a country: a general equilibrium analysis of the United Kingdom. *Energy Economics, 23*(4), 371-386.

European Commission. (2016). *International Carbon Market*. Retrieved from http://ec.europa.eu/clima/policies/ets/linking/index_en.htm.

Flachsland, C., Marschinski, R., & Edenhofer, O. (2009). To link or not to link: benefits and disadvantages of linking cap-and-trade systems. *Climate Policy, 9*(4), 358-372.

Gerardi, W., & Demaria, A. (2008). *Impacts of the carbon pollution reduction scheme on Australia's electricity markets*. Retrieved from http://lowpollutionfuture.treasury.gov.au/consultants_report/downloads/Electricity_Sector_Modelling_Report_updated.pdf

Hawkins, S., & Jegou, I. (2014). Linking emission trading schemes. Considerations and recommendations for a joint EU–Korean carbon market. *International Centre for Trade and Sustainable Development*.

Hoque, S., Dwyer, L., Forsyth, P., Spurr, R., Ho, T., & Pambudi, D. (2010). *Economic impacts of greenhouse gas reduction policies on the Australian tourism industry: A dynamic CGE analysis*: CRC for Sustainable Tourism Pty Limited.

Jaffe, J., & Stavins, R. N. (2008). *Linkage of tradable permit systems in international climate policy architecture*. National Bureau of Economic Research.

Kemfert, C., Kohlhaas, M., Truong, T., & Protsenko, A. (2006). The environmental and economic effects of European emissions trading. *Climate Policy, 6*(4), 441-455.

Kim, K. S., Tang, J. C., & Lefevre, T. (2004). Analysis on Dual System (Carbon Tax plus Emission Trading) in Domestic CO2 Abatement Strategy-CGE Analysis for Korean Case. *Journal of economic research, 9*(2), 271-308.

Lipsey, R. G., & Lancaster, K. (1956). The general theory of second best. *The Review of Economic Studies, 24*(1), 11-32.

McDougall, R., & Golub, A. (2007). GTAP-E: A revised energy-environmental version of the GTAP model. *GTAP Resource, 2959*.

Parliament of Australia. (2013a). *Chapter 1: Introduction and conduct of the inquiry*. Retrieved from http://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Economics/Completed_inquiries/2010-13/cleanenergypackageinternationalemissionstrading2012/report/c01.

Parliament of Australia. (2013b). *Emissions trading schemes around the world*. Retrieved from http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BN/2012-2013/EmissionsTradingSchemes.

Ranson, M., & Stavins, R. N. (2015). Linkage of greenhouse gas emissions trading systems: Learning from experience. *Climate Policy*, 1-17.

Siriwardana, M. (2015). Australia's new Free Trade Agreements with Japan and South Korea: Potential Economic and Environmental Impacts. *Journal of Economic Integration, 30*(4), 616-643.

Tuerk, A. (2009). *Linking emissions trading schemes*: Routledge.