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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 strategy will 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 model, namely the extended GTAP-E model, we found that Australia could 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. Overall, the results support the contention that any bilateral linkage is always better for Australia than operating its own domestic ETS alone.

Keywords: Australia; emissions trading scheme; ETS; linkage; marginal abatement cost; MAC; CGE model.

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1 Introduction

Since the last decade, many policy makers have considered emissions trading as a promising policy tool to tackle climate change issues. There are many emissions trading schemes (ETSs) 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 the USA, 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 other substantial benefits to economic systems such as cost-effectiveness of abatement, risk reduction of carbon leakage, reduction of price volatility and reduction of time-inconsistency problems for governments in policy implementation (Adams, 2007; Adams et al., 2014; Babiker et al., 2004; Hawkins and Jegou, 2014; Tuerk, 2009). The benefits will 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 and Jegou, 2014; Ranson and Stavins, 2016; Siriwardana, 2015). At present, there are ETS linkages between the EU members, and between the EU and Iceland, Liechtenstein, and Norway (see https://ec.europa.eu/clima/policies/ets_en). In Australia, the former Labour Governments (Rudd in 2007–2010; Gillard in 2010–2013; Rudd in 2013) had negotiated with the EU to link the Australian ETS with the EU-ETS after the success in implementing the carbon price mechanism in the domestic market (Department of Climate Change and Energy Efficiency, 2012). Under these negotiations, the first stage (2015–2018) would have been 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 a two-way link. In the proposal, the Australian Labour Government also desired to negotiate with other countries to link with its ETS[1] (Parliament of Australia, 2013a).

The most significant benefit of the linkage to participants is the opportunity to reduce the total costs of abatements in comparison to solely operating their own domestic ETSs. 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. This feature 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 (Babiker et al., 2004; Flachsland et al., 2009; Hawkins and Jegou, 2014; Jaffe and 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 the comparison of benefits, it is assumed that the proposed economies have their own domestic cap-and-trade ETSs and these schemes are compatible in order to unify their domestic ETSs into an international ETS. In each scheme, permits are entirely auctioned. In this paper, we will compare the potential net economic benefits gained by Australia from different bilateral ETS linkages with the EU, the USA, South Korea, Japan, China and India. Specifically, we will compare the macroeconomic outcomes and several industry results when Australia bilaterally links its ETS with different schemes. Consequently, we can observe which linkage may bring the highest net economic benefits to Australia. We assume that these selected economies implement the ETSs in order to achieve the targets announced at the 2015 Paris Climate Conference.[2] We use the computable general equilibrium (CGE) modelling approach, namely the extended GTAP-E model in the paper. The GTAP-E particularly suits for 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 accounting in the database, which is released from the production processes and combustion 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 were committed at the 2015 Paris Climate Conference. We assume that these ETSs are implemented in markets where there are no pre-existing distortions.[3] This is because the problem of 'immiserising growth' occurs when there are pre-existing distortions in partner economies (Bhagwati, 1958; Lipsey and Lancaster, 1956); hence, not all countries benefit from a linkage of ETSs (Babiker et al., 2004).

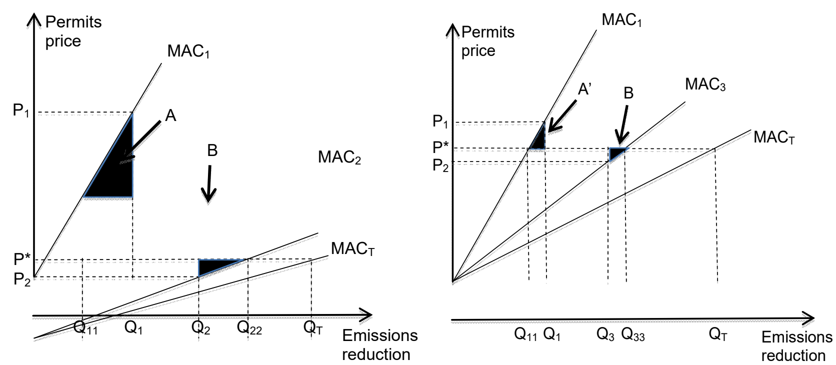
The rest of the paper is organised as follows: Section 2 describes the theory of MAC in the context of an international ETS, while a review of previous literature is provided in Section 3, Section 4 outlines the model, database and emissions targets used in this study, Section 5 presents the simulation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

2 Marginal abatement cost

MACs normally differ between countries. In some economies, MAC will increase considerably if they undertake a small amount of additional emissions reduction. However, many economies only experience low levels of MAC for every additional unit of abatement. Several reasons that resulted in 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 low emissions-intensive energy sources (e.g., natural gas) for high emissions-intensive energy inputs (e.g., coal), the greater the potential for a 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 will 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 may already have its production level at an optimal level. Therefore, reducing the level of production in order to lower its emissions levels would be an expensive option. Labour and capital costs are also major determinants of the MAC level of a country. If these 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 abatement.

When ETSs are linked together in an international ETS setting, participants may reduce the total cost of abatement by equalising their MACs. In such a linkage, all countries or regions may achieve economic benefits but 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 (see online version for colours)



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 Q1 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 MAC1 curve, while country 2 has a lower MAC curve, namely MAC2. 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 MACT) 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 areas A and B, respectively) compared to their own domestic schemes.

The net gains, areas A and B, however, are subject to change due to an alteration of 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, thereby 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 to 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 development of CGE models for environmental policy analysis (Babatunde et al., 2017). Economists and environmentalists therefore have reliable tools to quantify the comprehensive effects of these policies on various aspects of an economy.

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 author found that trading between power sectors across country borders would provide the highest efficiency gains, instead of restricting them to domestic markets where the electricity sectors receive permits at an auction price, rather than free. Babiker et al. (2003) stated that divergence from the domestic economy-wide cap-and-trade system increases economic costs. The EU economy is better off rather than having an economy-wide cap-and-trade system due to existing energy taxes in 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 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 traded across the borders, the abatement costs for all EU members were relatively low (at US$2 per tonne of CO_2). In such a trading scenario, Germany, the UK and the Czech Republic were the main sellers of emissions permits, whereas Belgium, Denmark, Finland and Sweden became the main buyers. Kuik and Hofkes (2010) examined the effects of the border adjustment for the EU-ETS on the carbon leakage and found that there would be a small reduction on the rate of leakage at national level. However, the reduction rate of leakage would be high for the steel industry but not for the mineral industry. Consequently, the border adjustment policy may greatly affect sectoral competitiveness rather than the national competiveness. Malina et al. (2012) found that the EU-ETS might only have small impacts on the US airlines and emissions. The carriers would increase profits, if they could pass on all additional costs to customers.

Qi and Weng (2016) found that a linked ETS is an efficient option to reduce emissions globally. Of these, the permit importers will enjoy lower production costs, higher demand for domestic production, thereby strengthening the production activities. The permit exporting countries, on the other hand, would experience increases in domestic consumption and investment due to revenue raised from selling permit overseas. Nong and Siriwardana (2017) investigated the effects of an international ETS market, including the EU, Norway, Switzerland, Kazakhstan, South Korea and New Zealand. They found that the volume of permit trading is relatively small because there are many small economies in the linkage. In addition, large economies would have considerable influence on the permit price, which make the trading permit price close to their domestic permit price. Zhang et al. (2017) examined the effects of an integrated ETS between China, the USA, EU, Australia-New Zealand, Japan and South Korea. Within the linked market, China would be a major exporter of carbon permits, which may reduce considerable abatement burdens for the developed countries. The authors also showed that the linkage particularly reduces unfavourable impacts on the high abatement cost countries, such as Japan and South Korea.

There are many studies which have 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) to evaluate the likely costs of an ETS on the Australian economy. The MMRF model is a dynamic CGE model, containing 52 industries, 56 commodities, eight 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 since the economy may grow strongly under an ETS. Adams also indicated that the compensation for energy cost increases could maintain the global competitiveness for Australian producers. In addition, the impacts on country's welfare may be moderated when revenue from selling permits is recycled effectively.

Gerardi and Demaria (2008) quantified the impacts of the carbon pollution reduction scheme (CPRS) on Australia's electricity generation sectors by using an integrated CGE modelling approach. This approach includes a suite of models, such as the GTEM model (to outline the international impacts), the MMRF model (to detail the domestic impacts) and the MMA's electricity market models (to present the sectoral impacts). In this approach, outputs of the other modelling simulations were the key inputs into the electricity market simulations. The simulation results indicate that the emissions levels of the Australian electricity sectors in all policy scenarios are far lower than the emissions level projected in the baseline. The authors also found that there is a strong transition to renewable energy industries in Australia. The renewable energy production is predicted to contribute half of the generation mix by 2050.

Hoque et al. (2010) used the MMRF-green model to assess the impacts of the CPRS-5[4] 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)[5] methodology. That is, the authors mapped the industry in the TSA and MMRF-green model industry. In the modelling, an initial price of emissions of A$25 per tonne is imposed in 2011 and the Australian industries can buy emissions permits from the international markets to meet their national obligations. The simulation results show that Australia only experiences a mild contraction in the economy at macro level compared to the baseline scenario. Most tourism industries experience small contractions only in their real outputs and some industries may have expansion. Specifically, the most adversely affected industries were the 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 the rail transport with an expansion in activity by 1.28%, since 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 2012–2013, rising 5% per year, projected to be around A$29 in 2015–2016. In Scenario 2, the starting carbon price in 2012–2013 was assumed to be at A$30 per tonne, rising to A$61 in 2015–2016. In both modelling scenario results, the real income of Australia still grows 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 affects the demand for labour as a result of reductions in output and capital growth; however, the national level of employment was unaffected. Labour moved across industries during the transition to a lower carbon economy, although the rate of movement was relatively low compared to normal rates of job turnover. In this study, pricing carbon may considerably change the composition of electricity generation in Australia. Electricity generation from renewable sources is estimated to be higher in both scenarios. Renewable generation may rise by 20% and 21%–26% of total electricity generation output by 2020 under Scenario 1 and Scenario 2, respectively. Initially, wind generation may develop quickly, but it may be overtaken by geothermal energy generation. The results also indicate that gas may 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 considered as 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, and Australia may need to buy half of its abatement required from overseas markets. However, Australia may experience a reduction in GDP by 1.1% in 2030 relative to the baseline.

Nong et al. (2017) investigated the effects of a proposed ETS on the Australian economy by using the MONASH-green model, which was extended from the MONASH model. They found that by 2030 the permit price would be A$41.3 per tonne of CO_2e. The Australian economy is only slightly unaffected by the proposed ETS. For example, real GDP may reduce by 0.86% in 2020 and 1.6% by 2030. However, the renewable energy sectors in Australia may increase substantially due to the implementation of the proposed ETS.

Siriwardana (2015) used the GTAP-E model in order to assess the effects on the economy and emissions levels of ETSs linkage between Australia, Japan and South Korea. The linkage was formulated 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 using the model. 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 became 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.

In Siriwardana's (2015) study, these three countries form an international carbon market, but our study only forms two countries in an international carbon market at a time (e.g., Australia and South Korea, and Australia and Japan). We also perform some other experiments by linking the Australian ETS with other schemes to observe the potential net economic gains to Australia subject to different bilateral linkages. It is worth in our study to examine more options for Australia to consider the most potential linkage, as Siriwardana (2015) showed that South Korea and Japan are expensive options for Australia in terms of linking ETSs. In addition, the linkages in our study are subject to the 2030 emissions targets instead of the 2020 targets considered by Siriwardana (2015). Our study also differs from other studies since we look at another aspect of the ETS linkages that can bring different benefits to a country. We form different international ETS markets between Australia and one of the other schemes at a time instead of integrating all ETSs in an international market.

4 Model and database

4.1 Model structure and database

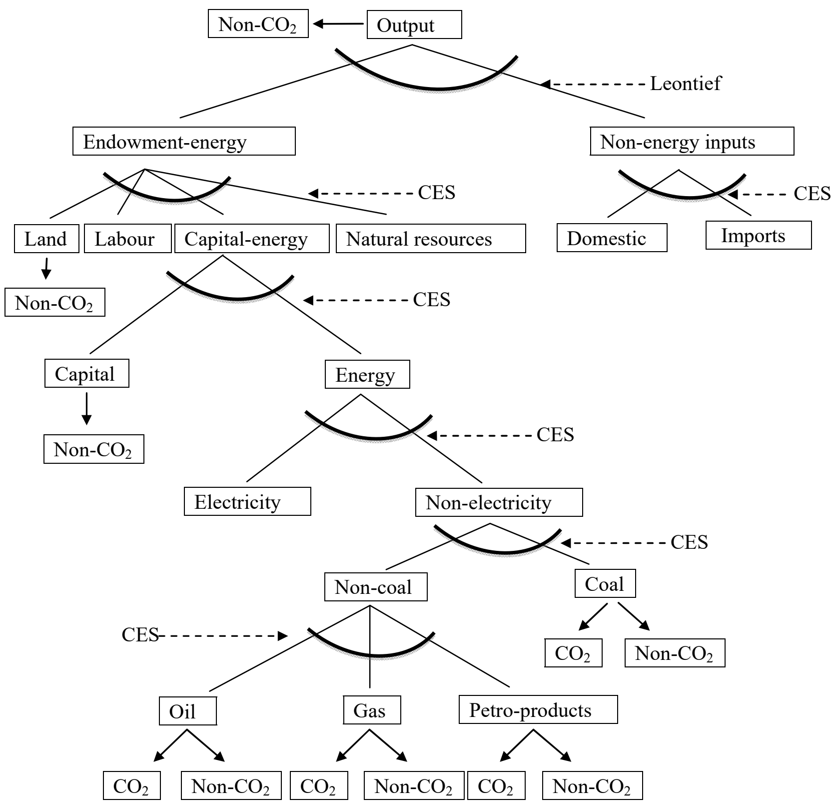
This study uses an extended GTAP-E model to quantify the net economic gains for Australia from different bilateral ETS linkages. The GTAP-E model is a global and comparative static CGE model, which contains multiple industrial sectors, one representative household and one representative government in each country/region. Consumers in GTAP-E are modelled to maximise utility, while firms or producers minimise costs. The model also contains market-clearing conditions, where supply of goods and services is 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 at the next level of CES function. At 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. 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.

The enhancements also include incorporation of non-CO_2 emissions [nitrous oxide (N_2O), methane (CH_4), 14 fluorinated gases (F-gases) (see https://www.gtap.agecon.purdue.edu/resources/download/3674.pdf)] in the database in addition to the original CO_2 emissions. The variables and equations related to these non-CO_2 emissions were also developed in the modelling in the same way as for CO_2 emissions. Consequently, the incorporation of non-CO_2 emissions allows us to capture the 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; hence, we allocated these emissions to firms and households according to the imported and domestic consumption values by these agents. Non-CO_2 emissions are released 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. 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 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 2 The production structure in GTAP-E model



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

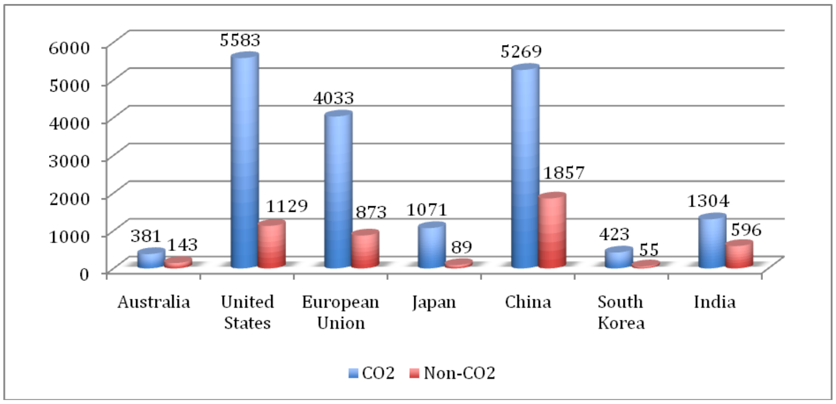
Figure 3 compares CO_2 and non-CO_2 emissions levels in different regions in the new database. If the database only includes CO_2 emissions, Australia, for example, only releases 381 Mt of emissions. When there is a presence of non-CO_2 emissions, Australia's emissions level increases significantly by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

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

	Australia		*USA*		*EU*		*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	1,205.2	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	2,413.94	20.7	1,340.1	11.36	442.85	0.95	2,957.41	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	1,124.16	182.73	56.16	13.45	198.41	15.94
Transportation	63.18	4.87	1,168.03	76.5	1,120.25	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	1,018.18	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	5,583.28	1,128.87	4,033.4	872.85	1,071.43	89.11	5,268.64	1,857.33	422.88	55.47	1,303.77	596.45

Source: GTAP-E database (base year 2007)

Figure 3 CO_2 and non-CO_2 emissions levels by country (MT) (see online version for colours)



Source: GTAP-E database (base year 2007)

In the modelling, we 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 can be projected separately, along with the fluctuation of total emissions. This flexibility allows us to focus on the type of emissions for a particular sector if necessary. For example, environmentalists would need to know the fluctuations of N_2O 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. In an ETS simulation, the emissions cap variables will be set exogenously, while the emissions prices and actual emissions variables[6] are endogenous in the model closure. However, in a carbon tax simulation, the emissions quota and actual emissions variables will be set endogenously, whereas the emissions price variables are set exogenously.

4.2 Emissions permit allocation and scenario design

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 set: 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 EU and India only have high levels of abatements, which are close to the sufficient levels. The emissions target of the USA 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:

$$\frac{CO_2\_e_{2030}}{GDP_{2030}} = (1 - \text{emission intensity reduction})^* \frac{CO_2\_e_{2005}}{GDP_{2005}}$$

$$\Leftrightarrow CO_2\_e_{2030} = (1 - \text{emission intensity reduction})^* \frac{GDP_{2030} * CO_2\_e_{2005}}{GDP_{2005}}$$

The GDP_{2005} of China and India are taken from the World Bank (2014a). This study assumed that GDP_{2030} of China is based on its annual GDP growth rate in 2005 (World Bank, 2014b), while GDP_{2030} of India is forecasted by the World Bank (2014c). Emissions of China and India in 2005 (CO_2e_{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.

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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 2). Such reversions are based on the average emissions growth rates in each economy from 2000 to 2010.[7]

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	EU	–40%	–17%
2005	USA	–28%***	–18%
2013	Japan	–26%	–6%
2005	India	–35%*	–17%

Notes: *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 USA submitted its emissions target by 2025.

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

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.

We propose several scenarios to compare the net economic gains for Australia when Australia moves from its domestic ETS market to different bilateral linkages. In all scenarios, emissions permits are auctioned and revenues from selling permits will be transferred to households in lump sum. In the first scenario, we assume that all selected countries have their own domestic ETSs and there is no linkage between any schemes. In the following scenarios, we assume that Australia will in turn bilaterally link its ETS with one of these other schemes; other countries, which do not link their ETSs with the Australian ETS, will implement their domestic ETSs.

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 high emission-intensive inputs. Linking with another scheme is also a valuable option to reduce its abatement costs.

Table 3 Macroeconomic effects on the Australian economy of different bilateral ETS linkages

Australian Index	*Bilateral ETS linking with*						*Domestic ETS*
	South Korea	*China*	*EU*	*USA*	*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

Note: Percentage changes.

Source: Model simulations

Table 3 shows some key macroeconomic effects on the Australian economy from its own domestic ETS and different bilateral ETS linkages with South Korea, China, the EU, USA, 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. These 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.

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 EU (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 a lower price of permits Australia will import emissions permits. Such a 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 to 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 EU-ETS or US$26,342 million if Australia operates its own domestic ETS.

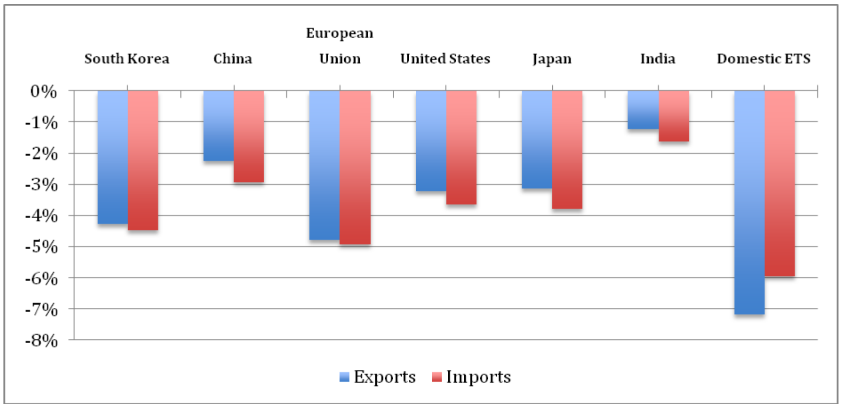
In the ETS simulation, the carbon price puts a cost on emissions, thus considerably increasing production costs. The carbon price also increases the cost of investment, subsequently reducing expected net rate of return and investment in capital stock. On the demand side, the ETS increases the overall price level as 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 the wage rates. The reductions in the 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 of Australia's commodities[8]; hence, the reductions in their demand for inputs would considerably affect the exports from Australia. As a result, Australia's exports will fall.

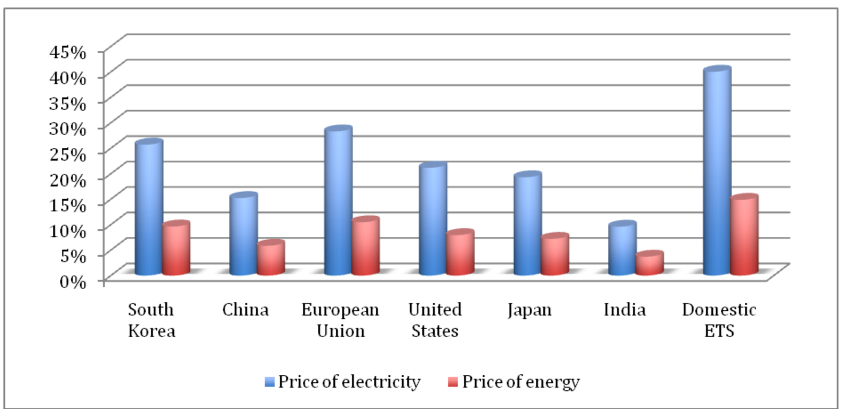
Similar to other macroeconomic findings, if Australia implemented its own domestic ETS, the effects on their exports and imports would be the worst relative to linking with any other schemes. Linking with India's scheme is still the best option for Australia in order to lower unfavourable effects on 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 (see online version for colours)



Source: Model simulations

Figure 5 Prices of electricity and energy in Australia in different scenarios (see online version for colours)

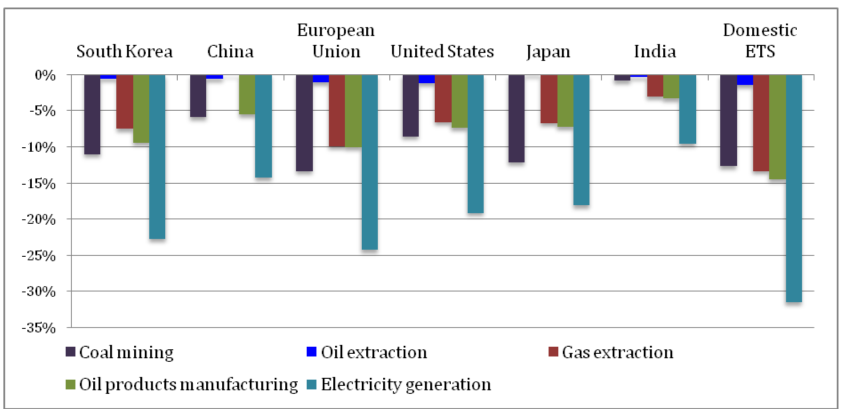


Source: Model simulations

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. On 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 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 the EU-ETS, while its price of electricity only increases by 9.6% in the case of linking with India's scheme.

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 (see online version for colours)



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 EU, South Korea, the USA, 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 for these 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, these 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 EU or South Korea is a very costly option for Australia, but it is still better than operating its own domestic ETS alone. The findings also suggest that the price levels for permits significantly affect the economies. The higher the price for permits the higher the level of unfavourable effects the country has to face.

6 Conclusions

This paper explores the theory of MAC in the case of linking two domestic ETSs. The purpose behind this is to examine which conditions are critical to obtaining net economic gains 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 to 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 EU, the USA, 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 of 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 EU. For example, the Australian real GDP reduces by –1.03% and 1.71% when Australia links its ETS with India and China, respectively, but its real GDP declines by 3.18% in the case of linking with the EU-ETS. In addition, the real Australian household income also reduces at much higher rate in the linkage with the EU-ETS compared to the linkages with these other schemes (e.g., the reduction is 2.16% for the linkage with EU-ETS, while the reductions are only 0.75% and 1.27% in the linkages with India and China, respectively). Linking with the EU-ETS also harms the Australian household welfare by US$20,939 million, but these negative effects are only US$7,317 million and US$12,186 million in the case of linking with India and China, respectively. However, the both 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.

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Notes

1 The ETS was unfortunately not implemented in Australia according to the plans proposed by the Labour Government. The coalition party, who formed the government in 2013, replaced the carbon price mechanism (or an ETS) by its Direct Action Plan (DAP) in 2014. Under the DAP, the government will use a budget up to A$2.55 billion to buy emissions abatement from polluters.

2 In Australia, although the DAP has been implementing, it has been critised by several scholars that the budget is inadequate to help Australia to achieve even the 2020 emission target (Clarke et al., 2014; Nong and Siriwardana, 2017). Hence, an ETS in Australia is still worth to consider, thereby, the authors aim to compare the potential net economic gains for Australia if it implemented an ETS and linked with other schemes in order to achieve the emissions target by 2030.

3 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).

4 The CPRS is an ETS 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.

5 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.

6 The actual emissions variables are the variables that measure the emissions levels released by the industrial sectors through their production processes, treatments of waste, fugitive emissions or agricultural activities. The emissions cap variables are the highest levels of emissions that allow industries to release. If the actual emissions are higher than their emissions caps, the industrial sectors need to buy extra permits from other sectors to fulfil their obligations, vice versa.

7 In order to get emissions in the same period 2000–2010, emissions for Australia, Japan, the USA and the EU are collected from UNFCCC, while emissions in this period for China, South Korea and India are gathered from the World Bank.

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