Environmental Impacts from a Joint Emissions Trading at Country Level

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Abstract

This paper examines the environmental and economic effects of six existing domestic national Emissions Trading Schemes (ETSs). We have expanded the analysis to a possible international ETS scenario among these schemes as these governments have shown an ambition to obtain a linked market and have been carrying out negotiations for many years. We incorporated non-CO_2 emissions into the GTAP-E model database and also modified it to estimate domestic ETSs with selected industries and obtain detailed projections regarding emissions permits allocation and emissions fluctuations. The results indicate that emissions trading volumes are very small in both scenarios, as Norway, Switzerland, New Zealand and Kazakhstan economies are very small compared with the European Union and South Korea. In addition, the results in international ETS scenario do not differ greatly from domestic trading scenario; however emissions abatement takes place with the lowest cost through international linkages.

Key words: existing national ETSs, linked market, GTAP-E model, non-CO_2 emissions.

1. Introduction

The Intergovernmental Panel on Climate Change has published five Assessment Reports on climate change over 20 years. It concluded that the global warming is unequivocal and has become more serious. The influence of humans on the climate system is real and climate change issues and abatement require substantial and sustained efforts of many countries in reducing Greenhouse Gas (GHG) emissions. However, Governments around the world have shown slow progress in efforts to address climate change issues, though most countries have ratified the Kyoto Protocol. The Parties to the Kyoto Protocol can meet their obligations either by reducing their GHG emissions or increasing their removals sinks or both. The Kyoto Protocol does not specify the mechanisms by which Parties must meet their emissions target but the emissions from removals sinks are very uncertain. Therefore, most Parties have considered policies related to industries' activities, i.e. carbon tax, fuel taxes, in order to ensure emissions to be under control and emissions abatement obligation could be met.

Since the early 1990s, many European countries introduced carbon taxes and fuel taxes, and some other countries and regions around the world also had similar legislation on GHG emissions in the following years. Recently, many countries and regions would prefer a cap-and-trade Emissions Trading Scheme (ETS) as it offers some outstanding advantages. A cap guarantees a country meets its emissions reduction target and it will drive investment in clean technologies. The market will determine the carbon price in the context of this cap, therefore enhancing the efficiency of the market. Cost-efficiency can be achieved because high abatement cost firms will purchase additional allowances whereas lower abatement cost firms undertake reductions. When the border of ETS is expanded, i.e. international ETS instead of domestic ETS, the emissions permits are more flexible to move between surplus emissions permits countries to deficit emissions permits countries. This flexible allocation will maximise the production capacity of participants, as it would reduce the price of carbon due to efficient allocation, market liquidity enhancement and a lower risk of carbon leakage, therefore reducing the cost of production.

By March 2015, there were only six economies, which have launched domestic emissions trading markets at country level[1]. Of these, the European Union has launched the regional ETS (EU ETS) since 2005 as a pioneer and the EU ETS is now in its third phase, which ends in 2020. The cap is currently lowered by 1.74% per year until 2021 in order to achieve its emissions targets according to the Copenhagen Accord and Cancun Conference (European Commission, 2015). In 2005, Norway also introduced a nationwide ETS with a scheme very similar to the EU ETS (Nordic Council of Ministers, 2007). Norway had committed to restrict its GHG emissions to no more than 1% above its 1990 levels for 2008-12. However, under the Copenhagen Accord, Norway further committed to reduce its GHG emissions by 30% by 2020 compared to 1990 levels, or 40% in the case of an international climate agreement (Hawkins & Jegou, 2014). In 2008, Switzerland and New Zealand introduced their national ETSs. The Swiss ETS became mandatory for large firms in February 2013 (Australia

[1] We consider EU as one economy.

Department of Parliamentary Services, 2013). New Zealand ETS initially covered only the forestry sector; however, it was amended and expanded to also cover stationary energy, fishing, industrial processes and the liquid fossil fuels sectors in 2010. The New Zealand Government has planned for its ETS to cover all sectors of the economy by 2015 (New Zealand Greenhouse Policy Coalition, 2015). In January 2013, Kazakhstan was the first Asian country to launch a national ETS. This scheme covers about 80% of national emissions (Australia Department of Parliamentary Services, 2013). In January 2015, South Korea launched the world's second-biggest emissions trading market. The cap for 2015-17 is set at 1.687 billion tonnes of CO_2e, including a reserve of 88 million tonnes of CO_2e for market stabilasation measures, early action and new entrants (Carbon market data, 2015).

The existence of these national ETSs provides the potential for a linkage between ETSs. A linkage among ETSs has been discussed for several years and can present many advantages. In this context, the EU agreed to link with other schemes and has a strong interest in establishing further linkages. Since 2006, the EU has expressed its interest aiming at building a global carbon market by 2020. It commenced such a linkage through an OECD-wide carbon market with comparable ETS systems and expects to extend this to major emerging economies by 2020 (Nordic Council of Ministers, 2007). In addition, the Norwegian Government has shown a strong desire for a linkage with the EU ETS; its ETS was significantly designed with future EU-compatibility. However, as a result of differences of opinions over how to establish the link, Norway and the EU are still involved in negotiating a linkage process (Hawkins & Jegou, 2014). Similarly, Switzerland and the EU have negotiated links of their ETSs since 2011. Australia is also another example with an ambition to link with EU ETS. Australia legislated to move to ETS and to link to the EU ETS in 2015. Economists expected the price of carbon permits and credits in the Australian market to converge with those in the EU scheme, which have been decreasing in value for the last few years due to oversupply (Australia Department of Parliamentary Services, 2013). However, the Abbot Government has abolished the Carbon Price Mechanism in Australia and intends to replace it with a Direct Action Plan, hence, the proposed link has disappeared.

In this paper, we examine a potential joint carbon market at current country level between EU, Switzerland, Norway, New Zealand, South Korea and Kazakhstan. We consider EU as one economy in terms of trading with these countries. South Korea is among the highest global GHG emitting countries; Kazakhstan is also a high polluting country, whereas emissions by Switzerland, Norway and New Zealand are relatively small compared with EU, South Korea and Kazakhstan. Therefore, a link of Kazakhstan's ETS and the Korean ETS with EU ETS provides a potentially efficient market while participation by the other three countries could present only small fluctuations in the system. However, participation by Switzerland, Norway and New Zealand with EU, South Korea and Kazakhstan ETSs provides an excellent example of international ETS. Such comparative data will encourage more countries and regions to join international ETS if the linkage significantly benefits small economies in terms of lower cost, market liquidity enhancement and many other advantages.

The scenarios for analysis of ETSs in this study are designed as follows: in scenario 1, called domestic ETSs, each of these six systems have their own domestic ETSs with cumulative emissions targets[2] until 2020 in order to achieve their emissions abatement obligation, other regions taking no action. In scenario 2, we analyse a joint ETS between these six ETSs, called international ETS. All industries in these six systems will join either domestic ETS or international ETS in the two scenarios. Either domestic or international ETSs are designed to sell permits by auction only.

The paper is organised as follows: Section 2 provides aspects of the linked market among ETSs. Section 3 discusses the potential challenges to linkage. Section 4 outlines the modified GTAP-E model with incorporation of non-CO_2 emissions and domestic ETS with selected industries. Section 4 also provides a way to calculate the cumulative emissions cap reductions for each economy in order to achieve their obligations in 2020. Section 5 indicates the modelling results of the two scenarios. Section 6 presents concluding remarks.

2. Aspects of the ETSs linkages

Type of ETSs

Under agreement between participants, linkage between ETSs can be either direct or indirect links. Direct link involves unilateral, bilateral, or multilateral trading. Of these, a 'unilateral link' is one-way trading between two systems, whereby emissions permits of system A are accepted in the market of system B, but not vice versa. It is because only one cap-and-trade system recognises allowances from the other systems or when a cap-and-trade system is linked to a baseline-and-credit system and the latter only produces permits but does not

[2] Each economy here has its own pathway target for each year to achieve obligations in 2020 under the Kyoto Protocol. The 2020 targets were set at Copenhagen and Cancun conferences. By applying the static GTAP-E model, we assess the effects of ETSs on economies in different scenarios according to the reduction pathway of these governments.

require firms to surrender allowances. Under a unilateral link, emissions trading occurs only when permits price in system A is lower than it in system B; the trading leads to a balanced price between these two markets where system A suffers a price increase and price is reduced in system B. Consequently, a more costly abatement in system B is replaced by lower-cost abatement in system A, thereby increasing emissions in system A and decreasing emissions in system B. By contrast, a 'bilateral link' is more flexible when permits are accepted in both systems, the allowances are therefore traded in either direction. The prices in the two systems are converged at an intermediate level. The 'multilateral link' is an expansion of the bilateral link of more than two systems. However, in practice, governments can intervene in trading markets by setting several restrictions and conditions. The imposition of a permit limit is a common preference; as such, market A is limited to buying permits of the other system's allowances for domestic compliance purposes. For example, at the first stage of linkage with EU ETS, Australia intended to apply a unilateral link with EU ETS and Australia planned to impose a quantitative limit by the use of Certified Emission Reductions and Emission Reduction Units at 50% of a company's compliance obligations in order to enhance compatibility with the EU rules in this area (Australia Department of Parliamentary Services, 2013). An Exchange rate is also a tool to require participants to surrender a higher number of allowances from the other system than domestic allowances for each tonne of their emissions. Exchange rates are prominent to guarantee environmental integrity in case of different amounts of emissions used between systems, or to ensure net emissions reductions will be achieved (Hawkins & Jegou, 2014).

'Indirect link' is just another aspect of multi-unilateral or multi-bilateral ETSs. It occurs when two systems A and B have a bilateral link agreement with system C but does not have an agreement with each other. The permits are still allocated among these three-systems through system C. One example of a multi-unilateral link is that systems A and B accept allowances from system C, but not vice versa. Hence, a change of permit demands by system A will affect the supply of permits available to system B.

<u>Advantages of the ETSs linkages</u>

Several benefits are soon recognised from linkage between ETSs, which make it an attractive policy option. One potential advantage is cost-efficiency gains as it enhances the available abatement opportunities across the linked systems. The mechanism facilitates participants to shift high-cost reductions from one system to lower-cost reductions in other systems in order to minimise total cost of emissions reductions. Consequently, emissions abatement takes place at the lowest cost (Hawkins & Jegou, 2014).

In addition, a broader market increases the liquidity and functioning of carbon markets, thereby reducing price volatility. A larger allowance market reduces concerns about unfair competitiveness when all participants face the same price. The market power is also limited because the increase in competition in a larger market lowers the potential for market manipulation (Michael & Brewer, 2009). These benefits can be significant if some systems are small (Jaffe & Stavins, 2008).

Another advantage refers to reducing the risk of carbon leakage. The risk will be lower for the system, where permits price falls. The third-party countries also have the potential to reduce the risk of carbon leakage through linked systems (Tuerk, et al., 2009).

Under bilateral or multilateral links, an institutional lock-in reduces time-inconsistency problems for government with limited power commitment. It therefore enhances the dynamic efficiency of climate policy. If firms are concerned about the government's commitment to climate change, they will slow their investment in low-carbon technologies (Flachsland, et al., 2009).

Disadvantages of the ETSs linkages

Although linkage presents considerable net gains, it also raises some demerits. In a multilateral market, some participants receive positive effects while others will lose. As prices will converge to an intermediate level under linkage, prices elsewhere in the pre-linkage scheme will be higher or lower than the convergent price. It determines the gainers and losers. For example, the buyers in the pre-linkage higher price scheme and sellers in the pre-linkage lower price scheme will gain; the respective sellers and buyers in these pre-linkage schemes will loss (Tuerk, et al., 2009).

The distributional effects are also a concern. In all current ETSs, the schemes do not cover all sectors, for example, most countries and regions just set schemes to cover energy-intensive sectors. Therefore, if the allowance prices increase due to linkage, it will increase of prices of energy and other energy-intensive goods. As a result, households and firms that do not directly participate in the ETS are also adversely affected (Jaffe & Stavins, 2007).

Furthermore, both energy-intensive firms and other firms, i.e. not under ETSs, face an increase of input prices, thereby affecting their competitiveness. Their competitiveness is weakened not only compared with firms outside the linkage system, but also the firms within the system as firms apply different technology and have different marginal costs.

The control by governments will be less effective over the design and impact of its own ETS as the effects from other markets in the linkage market are large. For example, the allowance price in the large pre-linkage system will significantly affect the price of the post-linkage. The small emissions market could be seen as a price taker. Hence, the decisions of the government of the smaller system will have little impact in the post-linkage market. However, the developments in the smaller system is not entirely isolated by the larger system, the intensive shocks in any system will affect the entire market. In addition, certain design features such as price caps and other cost containment measures can affect the entire market irrespective of issues from any system. The extent of control by a government over its own system also depends on the type of link. In addition, governments, which consider linking ETSs, need to sacrifice certainty of its ETS features as they may conflict with the other scheme's objectives (Tuerk, et al., 2009).

Linkage helps to reduce the risk of carbon leakage under certain circumstances but it also increases the risk in other cases. Countries may face a higher risk of carbon leakage when the allowance prices in their markets increase as a result of linkage (Tuerk, et al., 2009).

Firms might have perverse incentives to relax the emissions cap under a linkage, hence increasing revenue through the sale of allowances to other systems. This would undermine aggregate emissions reduction compared to a non-linkage scenario. For example, countries would not face a trade-off between value generation of allowance sales and the marginal environmental damage resulting from a less stringent emissions cap (Hawkins & Jegou, 2014). However, governments can intervene by issuing penalties or firms may face the threat of import quotas and fear the detection of the linkage partners from cooperation in other areas. Governments can also require a transparent disclose of mid-term and long-term cap plans prior to establishing the link (Flachsland, 2009).

Capital flows between countries under the linkage are also a concern though these flows benefit the participants in their trading. For example, large foreign currency inflows in the net allowance export countries will lead to increase of domestic wages and consumption.

Consequently, their currencies appreciate, thereby weakening their export competitiveness (Hawkins & Jegou, 2014).

Although there are many possible demerits of linkages, most of them, however, can be observed and predicted. Therefore, governments can have suitable legislation to control markets, reduce risks. In addition, governments can design appropriate policies to compensate low-income households and firms, thereby improving their competitiveness. As a result, the linkage will significantly contribute a major net gain to countries in the system, especially for the future environment.

3. Challenges for the linkages

The idea of linkage is clear and there are potential benefits; however, many countries and regions have been involved in linked negotiations for many years. Hence, there are obviously certain problems, which have delayed completion of the linkage progress. A particular issue is that ETSs have emerged in different political, economic and environmental situations. These differences are reflected in the design variations of schemes. Of these, some differences might have small impact or no impact on the process of linkage, but several differences are significant in preventing the formation of linkages.

Linkage between absolute target systems and intensity of target systems involves significant technical complexities. These complexities potentially raise concerns about cap intensity, competitiveness, and liquidity shocks; hence it could produce barriers towards linkage (Hawkins & Jegou, 2014).

A critical issue from the political point of views is the relative stringency of caps. It would not require a perfect balance between the caps adopted in different schemes, but at the level of aspirations, considerable differences are likely to make linkages politically unaccepted to both systems. For example, a large increase in allowance prices would occur in the less ambitious system, while a huge amount of financial outflows could happen in the more ambitious system (Hawkins & Jegou, 2014). The issue is not problematic, as it leads to an equalisation of prices across the linked system. However, whether a considerable difference in the stringency of the cap would make linkage politically acceptable is still questionable. In addition, in order to meet compliance obligations, firms in the more ambitious system are likely to purchase allowances from the less stringent system. Consequently, it leads to a violation of the Kyoto Protocol's supplementary principle (Sterk, et al., 2006).

Robust enforcement measures are important in order to prevent covered sectors from non-compliance. Governments usually issue a minimum level of stringency regarding enforcement. The penalty rates often differ between schemes, but they have to be high enough to ensure overall compliance and avoid making the penalty the default option (Blyth & Bosi, 2004). Hence, if penalty regimes in different systems do not act this way, a barrier to the linkage will strongly exist. For example, if a government does not require non-compliant entities to surrender the missing allowances by paying a set fine, the fine will then appear as a price cap. As a result, such a price cap would propagate into other systems through linkage and potentially makes linkage unattractive (Hawkins & Jegou, 2014).

Different rules between ETSs regarding the eligibility for offset credits could be a considerable barrier to linkage. Linkage will fail if credits excluded in one system are eligible in another system, given that it creates common offset credits for the linked schemes, thereby affecting the overall supply of units and subsequently prices. As a result, harmonising regarding the eligibility of offset credits is a significant requirement (Tuerk, 2009).

Other cost containment measures could constitute barrier to linkage. Borrowing and price caps issues are some examples. When such measures exist in one system, it would propagate effects in another system through linkage. Borrowing at high rates would result in delaying abatement activities and subsequently leading to a more costly abatement. Governments might prevent this by relaxing the cap; consequently undermine the environmental effectiveness of the scheme. On the other hand, if price cap acts in only one scheme, the government responsible for this scheme will determine the level of compliance costs for entities in both schemes. A low level of price cap reduces the environmental effectiveness of the linked schemes. Consequently, some countries might not join such a linked market (Hawkins & Jegou, 2014).

Current ETSs have different scope and coverage. In some cases, these differences might actually improve economic efficiency. However, if a scheme covers gases and sectors that cannot be monitored with comparable accuracy, it will build a barrier for other systems not to link with it. In addition, the different sectoral coverage between schemes also reduces the potential benefit in eliminating competitive distortions between the two systems. In such a case, distortions will prevail for sectors under ETS in one system but not in the other systems (Ellis & Tirpak, 2006).

In the real world, there are still many other concerns of governments causing them not to join a linked market. The differences in political issues, economic and environmental development targets, and current economic status need to be carefully considered. Action by other countries and regions would also be an indicator not only to have domestic climate change policies, but also to consider joining any linked carbon market scheme. Government changes within a country would be another reason for the delay as different political parties contesting government have different strategies and policies to tackle climate change issues or not to do so. In addition, as the process of linkage negotiation takes time, political fluctuation within a country will also affect the progress of negotiations. A country would have many other political issues to consider preventing a focus on how to action linkage progress. Some existing policies within a country, which relate to trading, environmental issues and tariffs, will be a concern along with the negotiations towards the linkage, as such a linkage would affect their economy and existing policies.

Given the possible barriers and difficulties the forgoing of linkages in international ETSs, it requires trade-offs among countries. There are still conflicting strategies, scheme designs, priorities and reconciliation between countries; hence, the linkages are still far from universal. However, many-year long-negotiation and efforts by many countries towards linkages raise hope that a global carbon market will be in effect in the near future. Such a market will include all sectors in all participating countries in a global effort to make a cleaner world. In this paper, we assume that all these six economies are at the highest level of ETS. It means that they will cover all sectors, have compatible ETSs, and are willing to join a direct multilateral link together, based on the absolute value of caps.

4. Model design and emissions targets

Model design

The model used in this study was developed from the original GTAP-E model, version 6.2 (McDougal and Golub, 2007). We have incorporated non-CO_2 emissions in the model, in addition to the original CO_2 emissions. In revising the database, we have assumed that the non-CO_2 emissions intensities for domestic and imported consumptions are the same; hence, we allocated the domestic and imported emissions consumption of firms and households, based on the imports and domestic consumption values by these agents. The incorporation of non-CO_2 emissions also involves the emissions from endowment usage and production activity, while the original CO_2 emissions in the model only include combustion emissions.

In addition, the way we have developed the model allows us to assess the fluctuation of CO_2 and non-CO_2 emissions separately. In the case of emissions trading, even the total emissions, CO_2e, are traded together; the fluctuation of CO_2 and non-CO_2 emissions of each institution will be reported independently, along with the fluctuation of total emissions. This flexibility is of benefit by allowing to focus on the type of emissions for a particular sector. For example, economists are likely to know the fluctuation of particular NO_2 and CH_4 emissions in land or water in agricultural sectors.

We have also developed this version of the model in order to make it more flexible in assessing climate change policies. For example, in the case of non-emissions trading, the carbon tax can be imposed in selected sectors. The domestic emissions trading can also be imposed within a group of selected industries while the level of international emissions trading is only an expansion of domestic emissions trading scenario. In addition, the way we have developed the model not only provides a flexible tool to evaluate climate change policies, but also enables us to achieve detailed results about industries such as emissions permits allocation and emissions fluctuation in each industry.

For this paper, we have aggregated the 57 sectors in the model into 20 sectors. Table A1 in the appendix shows this sectoral aggregation. In addition, there are 13 regions in the model; they are USA, Japan, China, Australia, India, net energy exporter group (EEx) and the rest of the world (ROW), in addition to 27 European countries (EU27), Switzerland, Norway, Korea, Kazakhstan and New Zealand, which are subject to the ETSs. We have separated USA, Japan, China, India, EEx and Australia from ROW though in this study they do not have any emissions trading activity, similar to other countries aggregated to ROW. We argue that each country in the model has different parameters and elasticities for economic reactions within each country and with other countries. Consequently, as they are the world's largest economies, treating them separately would have significantly different reaction from aggregating all of them in a group.

Emissions targets

According to the Copenhagen Accord and Cancun Conference, the economies have their emissions abatement obligation as shown in the last column of Table 1. Each economy has designed an emissions reduction pathway to achieve its target. As many countries and regions, except South Korea, already have domestic ETSs for some years, the cap reduction pathways have been in place for some years, not just from 2015. For example, EU27 has had its pathway to lower its cap by 1.74% since 2013, New Zealand had its from 2010. However, the cap reduction rates of these economies are unchanged until 2020 and we assume it is also intended to be unchanged for Kazakhstan and South Korea. In addition, our objective is to estimate the current ETSs, since 2015, in order to achieve the emissions targets in 2020. Therefore, based on these constant cap reduction rates we can calculate the cumulative reduction rates until 2020. As a result, the total effects of the current ETS subject to 2020 targets will be captured.

Table 1: Cumulative emissions cap reduction by country from 2015 to 2020

	Constant reduction rate per annum for 2015-20	Cumulative reduction in 2020	Emissions target in 2020
EU27	1.74% [a]	8.4%	20% below 1990 levels
Switzerland	1.74% [b]	8.4%	20% below 1990 levels
Norway	1.74% [c]	8.4%	30% below 1990 levels
New Zealand	1.3% [d]	6.3%	10% below 1990 levels
Kazakhstan	1.5% [e]	7.3%	15% below 1992 levels
South Korea	2%	9.6%	30% below BAU or 4% below 2005 levels

Note: a and c are collected from European Commission website (2014);
b is collected from Swiss Federal Office for the Environment website (FOEN, 2014);
d is gathered from New Zealand Greenhouse Policy Coalition website (2015);
e is gathered from Carbon Market Data website (2015a); and
the last column is collected from Center for Climate and Energy Solutions website (C2ES, 2015).

In Table 1, the constant cap reduction rate for South Korea in 2015 is calculated as follows: the total South Korean ETS allowances for phase I is 1,686,549,412. Of these, allowances in 2015 are 573,460,132; in 2016 are 562,183,138; and in 2017 are 550,906,142 (Carbon Market Data, 2015b). Hence, the allowances reduction for this period, or for 2015-20, is about 2% per annum.

The cumulative reductions in column 3 are calculated as follows:

$$\text{Cumulative reduction} = 1 - (1 - x)^5$$

where x is constant cap reduction rate per annum.

5. The modelling results and discussion

Environmental impacts

We first look at the environmental effects at the economy level over two scenarios in Table 2. The allowance prices are quite different when economies have their own domestic ETSs. Kazakhstan faces a very small price (US$2.8) relative to other economies, whereas allowance price is the highest (US$37.6) in Norway. There could be surplus allowances in Kazakhstan while the quota in Norway is relatively low. In fact, the price of allowances approached to zero when EU released a surplus allowances in 2007. During the recession, EU reduced its production levels, thereby automatically cutting emissions close to the allowance permits. As a result, there was no pressure for EU sectors in 2007 to meet their quotas. Another reason might be that the abatement cost of Kazakhstan's sectors is quite low relative to abatement costs in the other economies, especially Norway.

When all these economies join an international ETS, the allowance price becomes US$14.2. The price proves the theory that larger economies will significantly influence the allowance price of the linked market. On the other hand, larger economies could drive the emissions trading market, which makes the allowance price close to their domestic ETS prices. In this situation, EU27 and South Korea are much bigger economies compared to the other economies in the linked market hence the convergence of allowance price is very close to the prices of these two economies under the domestic ETS scenario.

In this study, a link among current ETSs at country level delivers some special characteristics. For example, New Zealand, Switzerland, Norway and Kazakhstan are very small economies relative to EU27 and South Korea in terms of economic scale, types of business and particularly emissions. From the database, the CO_2e emissions of New Zealand, Switzerland and Norway just rank from 50 Mega-tonnes (Mt) CO_2e to 78MtCO_2e; Kazakhstan has 240MtCO_2e compared to 478MtCO_2e of South Korea and 4905MtCO_2e of EU27. Consequently, the link among these economies is not highly efficient in terms of emissions trading. Table 2 displays emissions trading volumes with main traders of only Kazakhstan and EU27. However, the emissions volume trading is also still very small with selling of 42.7MtCO_2e from Kazakhstan and buying of 38.5MtCO_2e from Europe. The emissions trading value is obtained by multiplying volume by allowance price.

Table 2: Carbon price and emissions fluctuations

	NZL	EU27	SWL	NOR	KAZ	KOR
	Carbon Price (US$/tCO₂e)					
S1 - Dom ETSs	14.0	16.1	24.8	37.6	2.8	14.1
S2 - Joint ETSs	14.2	14.2	14.2	14.2	14.2	14.2
	Emissions trading value (US$ million)					
S1 - Dom ETSs	0.0	0.0	0.0	0.0	0.0	0.0
S2 - Joint ETSs	1.2	-547.9	-12.9	-53.8	607.3	6.0
	Emissions trading volume (MtCO₂e)					
S1 - Dom ETSs	0.0	0.0	0.0	0.0	0.0	0.0
S2 - Joint ETSs	0.1	-38.5	-0.9	-3.8	42.7	0.4
	Total CO₂e emissions of the whole country (% change)					
S1 - Dom ETSs	-6.3	-8.4	-8.4	-8.4	-7.3	-9.6
S2 - Joint ETSs	-6.4	-7.4	-5.5	-3.6	-24.9	-9.5
	Total CO₂e emissions from firms usage (% change)					
S1 - Dom ETSs	-6.8	-9.6	-10.8	-8.9	-7.5	-10.6
S2 - Joint ETSs	-6.9	-8.7	-8.1	-3.7	-25.6	-10.7
	Total CO₂e emissions from private usage (% change)					
S1 - Dom ETSs	-0.4	0.0	-0.3	-1.6	1.0	1.0
S2 - Joint ETSs	-0.5	0.0	-0.1	-0.6	5.2	1.0
	Total CO₂e emissions from government usage (% change)					
S1 - Dom ETSs	0.2	0.9	0.3	-1.1	0.2	1.6
S2 - Joint ETSs	0.2	0.8	0.3	-0.4	1.4	1.7

Note: S1–Dom ETSs refers to scenario 1, each of the six economies has its own domestic ETS.
S2–Joint ETSs refers to scenario 2, these six economies link their domestic ETSs.
NZL: New Zealand; EU27: 27 European countries; SWL: Switzerland; NOR: Norway; KAZ: Kazakhstan; and KOR: South Korea.

Other informative statistics of CO_2e emissions are also reported in Table 2. The CO_2e emissions reductions for the whole country under the domestic ETSs scenario are the same as the targets shown in Table 1. The CO_2e emissions reductions for each economy in case of international emissions trading scenario are different to targets set in Table 1; however, the total emissions reduction for the whole linkage is guaranteed due to emissions trading. The CO_2e emissions reductions for sectors are just small amounts adjusted from the whole country emissions reductions in both scenarios because the sectors are subject to either domestic or international ETSs.

The CO_2e emissions from private and government usage present mild fluctuations in both scenarios. Of these, emissions from private sector in New Zealand, Switzerland and Norway are reduced, while these measures are increased in Kazakhstan and South Korea. Interestingly, emissions from private usage in Kazakhstan significantly increase after joining its domestic ETS with the linked market (from 1% to 5.2%). This could be because the prices on emissions lead to reduction in energy demand, subsequently a fall in price of energy. The reduction in energy prices in turn significantly stimulates energy consumption by private consumers because they are not subject to the tax. It is also likely that energy demand by private consumers in Kazakhstan and South Korea are highly elastic relative to other economies or private consumption in other economies does not present high demand of energy. Furthermore, the production levels in New Zealand, Switzerland and Norway are reduced due to ETS schemes; hence the income of private sector might be reduced leading to a lower demand for energy commodities. As a result, emissions from private sector in these three countries are likely to decline.

In both scenarios, emissions from government usage slightly increase in most economies, except Norway. The situation is very similar to the case of private sector emissions. A price on emissions reduces demand on energy by firms. Thereby, the price of energy falls, in turn stimulating higher energy consumption for institutions that are not subject to the tax. Consequently, the emissions from government sectors are recorded at higher levels in most economies. The Norwegian economy might be different to the others. For example, government sectors might be closely tied with industrial sectors or government sectors play a very important role in the economy, hence, the overall production level reduction in the country becomes involved in a reduction in government production. The emissions in Norway are therefore reduced.

Table 3: Emissions trading volume by sectors in each economy ($MtCO_2e$)

Economy	NZL		EU27		SWL		NOR		KAZ		KOR	
Scenario	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Agriculture	0	0	-7	-11	1	1	0	0	-1	0	-2	-2
Coal	0	0	3	2	0	0	0	0	0	1	0	0
Oil	0	0	-1	-1	0	0	0	-1	-1	-1	0	0
Gas	0	0	-2	-2	0	0	0	0	0	1	1	1
Other minerals	0	0	0	0	0	0	0	0	0	0	0	0
Food	0	0	0	0	0	0	0	0	0	0	0	0
Textile	0	0	0	0	0	0	0	0	0	0	0	0
Wood products	0	0	0	0	0	0	0	0	0	0	0	0
Oil products	0	0	-9	-10	0	0	0	0	0	0	-2	-2
Chemical	0	0	-9	-10	0	0	0	0	0	2	-1	-1
Mineral products	0	0	1	0	0	0	0	0	0	2	2	2
Ferrous metal	0	0	0	-1	0	0	0	0	0	2	0	0
Other metals	0	0	0	-1	0	0	0	0	0	0	0	0
Metal products	0	0	0	0	0	0	0	0	0	0	0	0
Motor vehicles	0	0	0	-1	0	0	0	0	0	0	0	0
Electronic equipment	0	0	-3	-3	0	0	0	0	0	1	-1	-1
Other manufacturing	0	0	0	0	0	0	0	0	0	1	0	0
Electricity	0	0	105	84	0	0	0	0	5	31	13	13
Transport services	0	0	-63	-69	-1	-1	0	-2	-1	0	-6	-5
Other services	0	0	-15	-17	0	0	0	0	-2	2	-3	-3

Table 3 details emissions trading volumes by sectors in each economy in both scenarios. Sectors in New Zealand, Switzerland and Norway do not significantly get involved in emissions trading either domestically or internationally. Sectoral emissions trading activities are highly active in EU27. Of these, the electricity sector is a gainer when it sells 105$MtCO_2e$ and 84$MtCO_2e$ over domestic ETS and international ETSs scenarios, respectively. It is because electricity in EU27 is mostly generated by renewable and nuclear sources, which produce much fewer emissions relative to fossil fuels. Electricity generation from renewable and nuclear sources currently accounts for 50% of total electricity generation (World nuclear association, 2015). In Europe, both scenarios indicate that the high abatement cost sector such as Oil products manufacturing; Chemical, rubber and plastic manufacturing; Transportation; and Services sectors are potential buyers. Most sectors in Kazakhstan and South Korea only have small amounts of reserve permits for trading. In Kazakhstan and South Korea, only the electricity sector has some permits to sell. Interestingly, the electricity sector in both economies present some permits to sell as thermal fuel accounts for a very large amount in generating electricity. Perhaps, the emissions quotas are set at high levels for this sector in both economies, or the electricity sector in both economies has low abatement costs relative to other sectors in the domestic economy or international economy. In fact, the electricity sector, which mainly uses fossil fuels, presents high emissions intensity or low output per emissions. As a result, this sector could achieve a lower abatement cost relative to other sectors. Hence, through either domestic or international ETSs, this sector could find a cost-efficiency for selling its permits rather than to keep generating electricity. In fact, Kazakhstan's electricity sector increases its permits to sell from domestic ETS to international ETS scenarios when the price of allowances greatly increases over scenarios. The electricity sector in South Korea has the same amount of permits to sell over the two scenarios, as the price only slightly changes moving from domestic to international ETSs scenario.

Table 4: The actual CO_2e emissions fluctuation by sectors in each economy (% change)

	NZL		**EU27**		**SWL**		**NOR**		**KAZ**		**KOR**	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Agriculture	-6	-6	-8	-8	-29	-29	-8	-3	-2	-8	-1	-1
Coal	-7	-7	-17	-16	-20	-14	-20	-15	-6	-18	-12	-12
Oil	0	0	-2	-2	-25	-15	-1	-1	-1	-2	-35	-35
Gas	-6	-6	-6	-6	-50	-34	-12	-6	-3	-15	-61	-61
Other minerals	-7	-7	-8	-7	-7	-4	-9	-4	-2	-11	-4	-4
Food	-20	-20	-10	-9	-12	-7	-17	-8	-8	-27	-4	-4
Textile	-16	-17	-9	-8	-11	-7	-17	-9	-15	-48	-9	-9
Wood products	-20	-20	-10	-9	-12	-7	-14	-6	-13	-41	-5	-5
Oil products	-3	-3	-3	-3	-4	-2	-6	-3	-1	-7	-3	-3
Chemical	-6	-6	-5	-4	-9	-5	-8	-3	-11	-40	-4	-4
Mineral products	-18	-18	-11	-10	-25	-17	-24	-12	-15	-47	-19	-19
Ferrous metal	-17	-17	-10	-9	-18	-11	-32	-15	-6	-25	-10	-10
Other metals	-14	-14	-8	-7	-10	-6	-5	-2	-5	-21	-6	-6
Metal products	-12	-12	-9	-8	-8	-5	-19	-8	-3	-14	-5	-5
Motor vehicles	-12	-12	-9	-8	-9	-6	-34	-21	-6	-25	-6	-6
Electronic equipment	-2	-2	-2	-1	-3	-2	0	0	-16	-49	-1	-1
Other manufacturing	-12	-12	-6	-5	-9	-6	-21	-9	-14	-45	-11	-11
Electricity	-10	-10	-17	-16	1	2	-9	-3	-13	-42	-17	-17
Transport services	-6	-6	-4	-4	-6	-3	-9	-4	-2	-10	-4	-4
Other services	-7	-7	-5	-4	-8	-5	-7	-3	-3	-11	-3	-3

Table 4 shows the total CO_2e emissions fluctuation by sector in each economy in both scenarios. Generally, CO_2e emissions reduction by sectors in New Zealand, Europe and South Korea present similar amount of reduction rates from domestic to international ETS scenarios. Relatively high differences in emissions reduction rates between two scenarios occur in the other three economies. Emissions reduction rates by each sector vary significantly over economies. In the largest economy (EU27), the electricity and coal mining sectors present the largest percentage reduction rates, as they are relatively low abatement cost sectors. Consequently, these sectors are the sellers of permits as shown in Table 3.

We know exactly which sectors are buyers and sellers from Table 3, and from Table 4 we have information on the actual emissions reduction rates by sectors[3]. As we mentioned, New Zealand, Switzerland and Norway present very small amounts of emissions for trading as shown in Table 3. However, some sectors in these economies show some very high reduction rates such as 29% for Agriculture and 50% for the Gas sector in Switzerland in scenario 1, or the Ferrous metal sector in New Zealand, Switzerland and Norway in both scenarios. Logically, these sectors present very low amount of emissions. Similarly, high emissions reduction rates are evident in some sectors in Kazakhstan in Table 4, which correspond with small amounts of emissions for trading as shown in Table 3, indicating that these sectors are very small polluters.

Macroeconomic and welfare effects

Table 5 shows the macroeconomic effects over the two scenarios. All economies experience slight reductions in real GDP in both scenarios because ETSs put extra costs on production. Consequently, production levels are relatively reduced in real term. High fluctuations in real GDP are experienced in Norway and Kazakhstan over the two scenarios because Norway gains a huge reduction in price of allowances (from US$37.6 to US$14.2 as shown in Table 2) when moving from its domestic ETS to an international ETS. By contrast, Kazakhstan faces a much higher price in the linked market relative to its domestic ETS (US$14.2 compared to US$2.8 as shown in Table 2). In addition, both of these economies are heavily rely on petroleum-related industries. Kazakhstan also has relatively large building sectors, which are high energy-intensive. As a result, the linkage significantly affects production costs of these two countries through changes of allowance prices, subsequently reducing in production levels.

Inflations for these economies are relatively small in both scenarios as prices of inputs increase insignificantly; only Norway experiences a mild deflation of 0.2%. It is likely that demand in Norway strongly reduces as a result of introducing ETS, thereby price falls. This could be because that the demand is more elastic than the supply in Norway, hence, when

[3] A higher actual emissions reduction rate for a sector (i.e. number in Table 4) means the more permits that a sector can obtain to sell because its actual emissions become lower than its emissions quota.

extra costs of ETS on production reduce supply, the price goes up. An increase in price in turn makes demand significantly decline.

Reduction in production levels also results in declining of exports and imports of these economies. However, the differences of these trade responses between two scenarios are very small. Larger fluctuations in exports and imports over two scenarios still occur for Norway and Kazakhstan as a result of slightly large changes in real GDP.

Table 5: Macroeconomic effects

	NZL	EU27	SWL	NOR	KAZ	KOR
			Real GDP (% change)			
S1 - Dom ETSs	-1.0	-0.7	-0.3	-1.5	-0.7	-0.9
S2- Joint ETSs	-1.0	-0.6	-0.2	-0.07	-3.0	-1.0
			Consumer Price Index (CPI) (% change)			
S1 - Dom ETSs	0.2	0.3	0.2	-0.2	0.1	0.4
S2- Joint ETSs	0.1	0.2	0.1	-0.2	1.0	0.3
			Exports value (% change)			
S1 - Dom ETSs	-1.4	-0.9	-0.2	-1.3	-0.6	-1.2
S2- Joint ETSs	-1.5	-0.7	-0.1	-0.9	-1.7	-1.3
			Imports value (% change)			
S1 - Dom ETSs	-1.5	-0.8	-0.3	-1.9	-0.7	-1.3
S2- Joint ETSs	-1.5	-0.7	-0.1	-0.9	-1.7	-1.3
			Terms of trade (% change)			
S1 - Dom ETSs	0.5	0.1	-0.1	-0.1	-0.3	0.3
S2- Joint ETSs	0.5	0.1	-0.1	-0.3	0.2	0.3

Given the gains in environmental effects by reducing GHG emissions, these economies also face a considerable trade-off in many other sectors of their economies. For example, Table 6 reports some fluctuations in terms of welfare. In the case of domestic ETSs, all these economies experience large changes in equivalent variation (EV). Of these, EU27, Norway and South Korea are reported with the biggest reductions. A noticeable loss in welfare in Norway might be because Norway's welfare system significantly relies on a financial reserve produced by exploitation of natural resources, particularly oil. Hence, the reduction of oil production considerably contributes to the fall in welfare. Reductions in welfare in EU27 and South Korea are acceptable relative to sizes of these two economies. However, the welfare loss in Norway might be significant as this country already presents a very high burden of taxes. In addition, welfare in these economies has been improving when moved from domestic to international ETS except in Kazakhstan. It is expected when Kazakhstan faces a considerable higher emissions price when moving to international ETS, the economy is weakened significantly as shown by a reduction of 3% in the real term of GDP. Consequently, Kazakhstan's welfare is worsening in the case of international ETS compared to the domestic ETS.

Real wage rates of skilled and unskilled labour generally experience slight reductions over the two scenarios. Most economies show small fluctuations, about 0.1%, of these measurements when moving from domestic to international ETS. Only Norway and Kazakhstan shows relatively higher changes because the price of emissions considerably changes over two scenarios in these two economies. The reductions in real wage rates are explained by reductions in real GDP, thereby reducing demand for labour and leading to reductions in real wage rates. When real wage rates decline and incomes fall, the private consumption in all these economies reduces in a consequent manner. However, the differences between two scenarios are very small and the percentage reductions are relative small. In this regard, only private consumption in Switzerland experiences an increase of 0.1% in both scenarios as real wage rates and real GDP in Switzerland are only slightly reduced.

Table 6: Welfare impacts of the two scenarios

	NZL	EU27	SWL	NOR	KAZ	KOR
			Private consumption (% change)			
S1 - Dom ETSs	-0.5	-0.2	0.1	-1.2	-0.2	-0.2
S2- Joint ETSs	-0.5	-0.2	0.1	-0.6	0.3	-0.2
			Real wage (skilled labour) (% change)			
S1 - Dom ETSs	-1.0	-0.5	-0.1	-1.4	-0.7	-0.6
S2- Joint ETSs	-1.1	-0.4	0.0	-0.7	-2.2	-0.7
			Real wage (unskilled labour) (% change)			
S1 - Dom ETSs	-1.2	-0.5	-0.1	-1.4	-0.8	-0.6
S2- Joint ETSs	-1.2	-0.5	0.0	-0.7	-2.9	-0.6
			Equivalent variation (EV) (US$ million)			
S1 - Dom ETSs	-715	-62,735	-497	-3,457	-381	-3,713
S2- Joint ETSs	-728	-55,714	-330	-1,909	-618	-3,746

6. Conclusion remarks

Given national ETSs that are currently performing in some economies with targets to achieve their emissions abatement obligations in 2020, we examined the effects of these separated domestic ETSs on their environments and economies using the GTAP-E model simulations. We then joined domestic ETSs to form an international ETS to ascertain whether the linkage might provide significant benefits to these economies. In addition, the governments of the countries examined are also ambitious for a joint carbon market and have been undertaking such negotiations for many years.

Our simulation results show that the emission prices highly vary over economies in the case of domestic ETSs. Of these, Norway shows the highest abatement costs whereas Kazakhstan presents the lowest abatement costs, as prices are very high in Norway at US$37.6 and very low in Kazakhstan at US$2.8 per tonne of abatement. We observe that the price is converged to an intermediate price in the case of international ETS and which is closer to domestic ETS prices of large economies such as EU27 and South Korea. Norway and Kazakhstan are likely to experience significant changes in prices. The noticeable differences in prices in Norway and Kazakhstan in turn result in higher fluctuations in macroeconomic and welfare measurements relative to other economies. It is also worth noting in this situation that the bigger economies drive the convergent price in a linked market.

It is not surprising that the trade volume in the international ETS is not large as the linkage involves many small economies, in terms of business, trading and emissions, such as those in Switzerland, Norway, New Zealand and Kazakhstan. Even in a domestic trading scenario, the amounts of trading are negligible in these economies.

Over the two scenarios examined in this paper, economies experience only slight reductions in their real GDP and acceptable levels of inflation. However, these economies suffer from relatively high reductions in welfare. Generally, there is not much difference in reported projections, except welfare, when we compare the domestic ETSs scenario with the international ETS scenario. This is because most economies in the linked market are very small relative to EU27 and South Korea. Hence, a more efficient linkage would be likely involving large economies or polluters such as United States, Japan, China, India or Australia. However, the scenario in this paper when examining the international linkage also provides a good example of a possible wider international linkage. Such a linked market would also reduce market power and carbon leakage. In addition, the results also indicate that the six economies in this study can achieve their targets at very low costs under an international ETS framework.

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Appendix

Table A1: Commodity aggregation

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

Source: Database in GTAP-E version 8.1