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Insights from ASEAN-wide emissions trading schemes (ETSs): A general equilibrium assessment

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ABSTRACT

ASEAN has not yet had any joint policy to constrain emission levels in the context of global efforts to tackle climate change and studies on such issues in the region are still scarce. This study employs a global computable general equilibrium (CGE) climate change policy-focused and electricity-detailed model to examine the impacts of emissions trading schemes (ETSs) on the ASEAN member economies. We found that Indonesia (a permit buyer) experiences much lower economic costs in the regional ETS scenarios rather than in its closed ETS market (−9% compared to −16% in real GDP). Malaysia, the Philippines, Singapore, Thailand and Vietnam act as permit sellers and experience higher economic costs in the regional ETS scenarios. It is because the balance on the current account, which is equal to the sum of the ordinary trade balance and net emissions trading revenue, is assumed to be fixed. Furthermore, the change in ratio of trade balance to regional income is also fixed. Such a setting indicates that if the net permit trading revenue is used to fully compensate for the trade balance, which is also maintained along with the changes in the regional income, permit selling countries will be worse off and vice versa if they move from their domestic ETS markets into a regional ETS market. Results also show that technological improvements can help reduce economic costs of the ETSs. In addition, renewable energy sources show strong expansions in their production levels, but they are still far from becoming dominant in ASEAN in order to significantly reduce economic costs of climate change policies. Households will also increase their demand for renewable energy in all ASEAN countries while lowering demand for fossil-based energy; however, this sector will still experience reductions in the overall electricity demand due to previous strong reliance on fossil-based energy.

1. Introduction

Emissions trading schemes (ETSs) or carbon taxes (Garnaut, 2008) have been considered and implemented to constrain greenhouse gas (GHG) emissions in many countries, including the European Union, Australia, New Zealand, South Korea, Japan, China, South Africa, Singapore, and Chile (Simshauser and Tiernan, 2019). In Southeast Asia, all countries ratified the United Nations Framework Convention on Climate Change (UNFCCC),[1] and many countries in the region have studied carbon taxes or ETSs, including Vietnam (Nong et al., 2020), Singapore,[2] Thailand (Wattanakuljarus, 2019), Indonesia and the Philippines.[3] The Southeast Asian region, however, does not have any mechanism or a regional climate change policy to jointly reduce countries' emissions levels together. Eleven countries[4] formed the

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[1] https://unfccc.int/process/parties-non-party-stakeholders/parties-convention-and-observer-states.
[2] https://www.nea.gov.sg/our-services/climate-change-energy-efficiency/climate-change/carbon-tax.
[3] https://icapcarbonaction.com/en/ets-map.
[4] ASEAN now includes 11 countries members such as Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Timor-Leste, and Vietnam. ASEAN was established in 1967 by five members.

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Association of Southeast Asian Nations (ASEAN) in 1967 with many mechanisms to facilitate the economic development of the region, such as forming the ASEAN Free Trade Agreement (AFTA) (Ariyasajjakorn et al., 2009), establishing the ASEAN Economic Community (Opasanon and Kitthamkesorn, 2016), and negotiating FTAs with China, the European Union, Japan, the United States, Australia, etc. (Robles, 2008; Li et al., 2016). It is thus plausible for ASEAN to study and develop a joint mechanism that allows member countries to reduce emission levels cooperatively.

Crucial questions are to find out the potential impacts of ETSs on individual countries' economies and whether all countries are always better off when moving from their own countries' domestic ETS markets to a regional ASEAN ETS. In addition, which factors are the main components affecting abatement costs in these countries. Babiker et al. (Babiker et al., 2004) stated that when two countries with different marginal abatement cost curves join their ETSs together, it is not necessary that these two countries are both better off. That is, they are both better off if there are no distortionary taxes in these markets. On the contrary, Babiker et al. (Babiker et al., 2004) proved that when distortionary taxation exists, the buyer country can improve its economic performance, but welfare in the seller country can increase or decrease depending on the levels of the distortion.

Such a research agenda, however, has been left behind in the literature with major gaps to examine potential impacts of a regional ASEAN ETS or other climate change policies on the economies of particular member countries and collectively. This study aims to close the research gaps in this regard by examining the impacts of the ETSs on each country member of ASEAN in different scenarios. Specifically, we compare the impacts of domestic ETSs versus a regional ETS on the economies of member Countries. These core scenarios are additionally considered in the case of renewable energy technology development. The emission targets are set to follow their Intended Nationally Determined Contributions (INDCs) submitted to the UNFCCC to reduce emission levels by 2030. The simulations are carried out by using the global computable general equilibrium (CGE) climate-change-policy and electricity-detailed model (GTAP-E-PowerS) (Nong, 2020). In the literature, economy-wide impact studies of ETSs, carbon taxes, and emissions abatement subsidies, have been widely carried out using CGE modelling approaches (Zhang et al., 2016) in different countries, such as in the European Union (Hermeling et al., 2013; Vrontisi et al., 2016), China (Lin and Jia, 2020; Li et al., 2018), the United States (Brown et al., 2020), South Korea (Choi et al., 2017), Australia (Tran et al., 2019), New Zealand (Lennox and Van Nieuwkoop, 2010), Chile (Benavente, 2016), and South Africa (Alton et al., 2014).

This study has multiple important implications in both academic and public domains.

- Studies on the impacts of climate change policies in ASEAN are limited in number. There are several studies focusing on different country members, but studies considering a regional climate change policy are scarce, providing an opportunity for the current study to bridge these research gaps.
- Considering climate change policies in different scenarios, particularly including technology development and transitions from closed (domestic) to open (a joint regional scheme) settings is useful and informative for policy makers to consider a real mechanism in the future development of regional legislation. It is also informative for the public to foresee the likely impacts on the economies of the region once such policies are introduced. The study also has practical implications since most countries in the region are still under consideration to introduce ETSs in their countries (only Singapore has currently implemented a carbon tax, but at a small rate of S$5 per tCO_2e). Hence, findings in this study become useful reference for policy- and decision-making processes in all country members. Whether a regional ETS in ASEAN is an appropriate option for the region to follow and in which mechanism is a likely matter for investigation.
- This study examines the roles of renewable technology development to see whether it can help reduce costs of climate change policies in ASEAN. In addition, whether growth of renewable energy is adequate to compensate for declines in fossil-based power to ensure energy security.

The rest of the paper is organised as follows. Section 2 reviews relevant literature related to climate change policy studies in the regions. Section 3 highlights the methodology, database and scenario design. Section 4 analyses the modelling results, while Section 5 extends the discussion. Section 6 provides concluding remarks.

2. Review of climate change policy studies

Studies on climate change policies in the ASEAN region are relatively limited. This is mainly because climate change policies have only been discussed recently and are still unclear concerning future implementations of these policies in each country member. Another possibility would be the lack of research resources and interest. In this regard, only Singapore has implemented a carbon tax at S$5 per tonne of CO_2e since January 2019. Li and Su (2017) employed a national CGE model for Singapore with a database in 2010 to examine the impact of a carbon tax of S$10 per tCO_2e over various scenarios. At this rate, the real GDP in Singapore declines by mere less than 0.1% across scenarios. The emission levels also reduce at small rates between 1.6% and 2.7%. Exports of refinery products, however, shows high reduction rates from 5% to 6.3%. Wattanakuljarus (2019) developed a CGE model for Thailand to examine the impact of a carbon tax policy on the economy of the country, as well as their households. The emission target was to enable Thailand to achieve the 2030 target by reducing 20% of the emission level compared to the business as usual. The carbon tax rate is relatively small at less than $1.5 per tonne of CO_2e to achieve such a target. As a result, the real GDP declines by less than 0.16% by 2030 over such scenarios. Output of coal, however, will reduce at relatively high rates by around 4.4%. Different household groups are also negatively affected slightly by less than 0.25%. Saelim (2019) examined the impacts of a $37 per tonne of CO_2 in Thailand and concluded that total monthly welfare loss across household groups ranges from $22 million to $114 million of which rich groups lose more than low-income groups. Total monthly welfare loss for all household groups in Thailand reaches $260 million.

Corong (2008) also examined a small carbon tax rate of $2 per tonne of CO_2e in the Philippines to reduce the emission level by 1%. The impacts at the macro level are also found to be relatively small. Cabalu et al. (Cabalu et al., 2015) employed the PHILGEM-E model to investigate the impacts of a $5 carbon tax on the economy of the Philippines. Such a carbon tax enables the Philippines to reduce its emission level by 1.1% per annum, causing a cumulative 0.6% reduction in the real GDP in 2020, but the real GDP in the Philippines improves by 1.8% once 2% energy efficiency improvement in industrial sectors is included. The Philippines further increases its real GDP by a cumulative 2% in 2020 when the economy forces 10% transformation from fossil-based electricity generation to renewable-based electricity generation in 2015-20.

Coxhead et al. (Coxhead et al., 2013) converted the energy tax rates in Vietnam into to carbon tax rates and found that the real GDP in Vietnam declines by 0.4–0.6% across scenarios. Energy sectors are significantly affected with a decline in the output level of crude oil by 8.6%, of petroleum product manufacturing by 5.1%, and of coal mining by 4.1%. Nong et al. (Nong et al., 2020) employed the GTAP-E model to examine the impact of an ETS in Vietnam subject to the 2020 target. The carbon prices range from $35 to $109 per tonne of CO_2e with real GDP reductions from 1.1% to 3.8%. Energy sectors are substantially affected with output declines by 12–22% for the coal mining sector and 13–31% for the electricity generation sector over the scenarios. Yusuf and

Resosudarmo (2015) used the ORANI-G model to examine the impact of the carbon tax in Indonesia. It is surprising that a $30 carbon tax per tonne of CO_2 causes the real GDP in Indonesia to decline by less than 0.1%. Solaymani et al. (Solaymani et al., 2015) recommended that a carbon tax is more effective than an energy tax for Malaysia to reduce its emission levels. At a rate of 15% emission reduction, a carbon tax induces Malaysia to experience its real GDP reduced by 1.4–1.5%, while an energy tax imposes a decline in real GDP by 1.7–1.8%.

The review of literature indicates that there are only a few studies in each of these ASEAN countries and their scope of the scenarios are still limited. In addition, studies on climate change policies in all countries together (i.e., ASEAN as a group) are extremely scarce. No studies have been conducted to examine how the entire ASEAN region forms a regional ETS to jointly achieve the emission targets, which contribute to global emission abatement efforts. It also indicates that transitional impacts from domestic carbon schemes to a joint regional carbon market are muted, which are the focus in the present study.

3. Methodology

3.1. Modelling framework

This study employs a global CGE model (GTAP-E-PowerS), which was specifically designed for climate change policy studies. This is a GTAP-based model, which was widely used in the literature to study different climate change and tax-related scenarios and was extended by Peters (2016) to include various base-load and peak-load electricity generation technologies. In each generation of technology, there are fossil- and renewable-based resources of which these resources are substitutable for each other within each technology, but base load and peak load electricity commodities are uniquely without any substitution. The model was then developed further by Nong (2020) to improve the capacity of the carbon market and associated simulations.

Fig. 1 outlines the mechanism in GTAP-E-PowerS. The model includes numerous equations to represent the behaviours and reactions of actors in the model. All actors in each country's economy connect with each other to present complete activities of an economy. Countries are connected with each other via bilateral trade mechanisms. Households in Country A, for example, supply labour in order to receive salary payments used for their consumption of goods and services after paying income taxes to the government. Industries use primary inputs (land, labour, capital, and natural resources) and intermediate inputs produced domestically by other industries and internationally. Industries also pay consumption and production taxes to their governments. The differences between incomes and consumptions of the private and public sectors contribute to regional savings. Actors in Country B also act in the same ways.

All private, public and industrial sectors release GHG emissions from consumption of fossil fuels. Industrial sectors also emit emissions from consumption of chemicals, livestock capital, land (from agricultural sectors), and production processes. However, we only illustrate GHG emissions released by industrial sectors for simplicity of which such GHG emissions are subject to carbon constraints. Industries with deficit emission permits can buy permits from industries with surplus permits in the domestic market or internationally if ETSs are linked between countries. The carbon tax revenues are then collected by the government in each carbon market to transfer to households in lump sum.

Fig. 2 highlights how constraining industrial emission levels would affect an economy. Specifically, when industrial sectors are forced to reduce their emissions to certain levels, it will determine an equilibrium price in the market on a unit of emission permit (e.g., 1 tonne of CO_2e) so that these industrial sectors have to pay for their emissions up to the constraining levels. All industries in such an economy react based on their potential to reduce their production levels, to switch to use lower emission-intensive inputs (e.g., petroleum products instead of coal), and to exchange emission permits with other industrial sectors. These activities force the whole economy to change, affecting demands for intermediate inputs and primary factors, as well as tax revenues of governments. It subsequently affects private and public incomes and consumption levels along with changes in intermediate demands to affect the commodity markets and corresponding prices. Price changes in turn affect demands by all sectors in an economy.

3.2. Database and scenario design

We employ the GTAP-Power database version 10 with a base year of 2014 (Aguiar et al., 2019). The database has 141 countries and 76 industrial sectors. Each region has one representative household group and one representative government. For the purposes of this study, we aggregated the world regions into 8 regions, covering the six main ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam), the 'rest of ASEAN' region including the remaining countries in the region (Laos, Cambodia, Myanmar, and Brunei Darussalam), and the 'rest of the world' (ROW) region. The 76 Industrial sectors in each country (and region) are also aggregated into 14 main sectors, including 8 energy sectors. Since the emission targets are subject to the year 2030 requirements, we follow the Shared Socioeconomic Pathways 2 (Fricko et al., 2017) to update the database from 2014 to 2030 based on the projections of GDP and population growth rates.

There are three ETS scenarios developed in this study. In all three scenarios, all industrial sectors are included in the schemes in each country and all emission permits are auctioned. All revenues are transferred to households in lump sum. Details of the scenarios are provided as follows.

- Scenario 1 (S1_dom): All ASEAN countries implement their own domestic ETSs subject to their 2030 emission targets submitted to the UNFCCC (Fig. 3).
- Scenario 2 (S1_domTech): The mechanism in S1_dom is applied. In addition, all industrial sectors experience 50% improvement in the renewable energy input augmenting technical change.
- Scenario 3 (S2_reg): All ASEAN countries in S1_dom join a regional ASEAN ETS with the same emissions abatement targets as applied in S1_dom and S1_domTech.

We assume 50% improvement in the renewable input augmenting technical change as renewable technology has been developed significantly to reduce construction and/or installation costs, particularly costs of solar panels with a decline by 80% in 2000-20.[5] When considering all renewable energy together, it would be reasonable to assume a lower level of technological improvement. It is indeed just an experiment in this study to examine how the impacts of a climate change policy are altered when it is accompanied by technology development.

In the simulations, we assume each industry in a corresponding country is forced to reduce their emission levels following the emission constraint in such a country. For example, Thailand is responsible for reducing its emission level by 20%; hence, it is assumed that the emission level of each industry in Thailand needs to be reduced by 20%. As a result, emission permits which are equivalent to 80% of all industries' initial emission levels are auctioned and allocated to each industry. Primarily, each industry in Thailand suffers emission costs equivalent to 80% of its initial emission level. If such an industry emits more than allocated permits (equivalent to 80% of its initial emission level), this industry needs to buy additional permits from other industries who sell their surplus permits. The mechanism is applied to all industries in all countries in the ASEAN region. In the domestic ETS settings (Scenarios S1_dom and S1_domTech), industries in any countries are only allowed

[5] https://www.paradisesolarenergy.com/blog/will-solar-panels-be-cheaper-in-the-future.

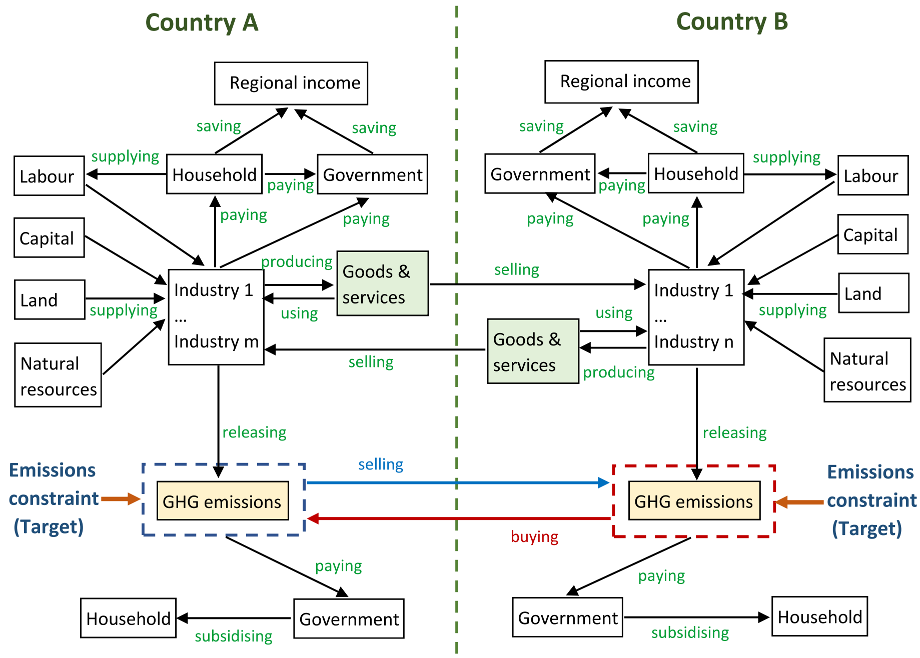

Fig. 1. The GTAP-E-PowerS modelling framework.
Note: the government in each country is identical, it is only separated into two boxes for better representation. It also applies to households.

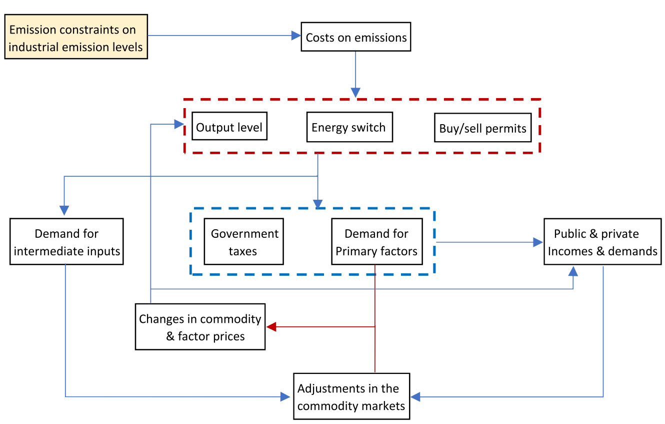

Fig. 2. Impact flows of emission constraints in GTAP-E-Power.

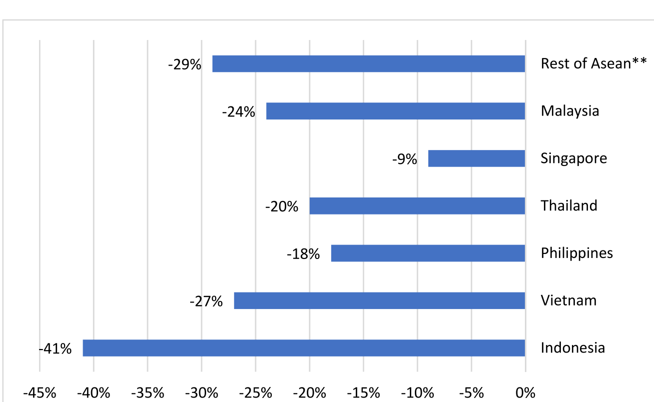

Fig. 3. The 2030 emission targets by region.
Source: https://www4.unfccc.int/sites/submissions/indc/Submission%20Pages/submissions.aspx

to trade their permits within their countries' boundaries. Moving from domestic ETS mechanisms to a regional ASEAN ETS (Scenario S2_reg) does not alter countries' emissions target stringency, it only expands the trading markets and provides opportunities for industries to trade permits internationally with industries in other ASEAN countries.

4. Result analysis

4.1. Overall assessment

Following the upward marginal abatement cost (MAC) curve theory, if countries have the same MAC, countries with higher abatement targets will experience higher abatement costs. Hence, countries with higher emission level abatements often suffer higher costs in their economies. In other words, emissions abatement targets are a key driver that affect countries' economies of which high emission abatement levels often result in higher unfavourable impacts on economies. Fig. 4 shows that Indonesia reduces its emissions level at the highest rate (−41%), resulting in the highest reduction in the real GDP (−16.1%) in Scenario S1_dom. It is followed by the 'rest of ASEAN' region with 29% reduction in the emission level and 13.8% decline in the real GDP. In this instance, Singapore experiences the lowest reduction rate in its economic performance with the real GDP reduction by only 1.5% because Singapore only aims to cut its emissions level by 9%. Vietnam, Thailand, the Philippines and Malaysia will experience moderate reductions in their real GDP compared to the economic contractions in Indonesia and the 'rest of ASEAN' region because of their low emissions abatement targets relative to those in these two regions.

There are, however, other determinants that alter impacts on economies, such as (i) shares of emissions released from production processes and the usage of primary factors (land and livestock capital), and (ii) shares of renewable energy.[6] Indonesia and the 'rest of ASEAN' region have relatively high shares of emissions released from production processes and the primary factors (land and livestock capital) relative to the

[6] Comments on possibilities to switch to low emission-intensive inputs are provided in Section 5 as a limitation in the model.

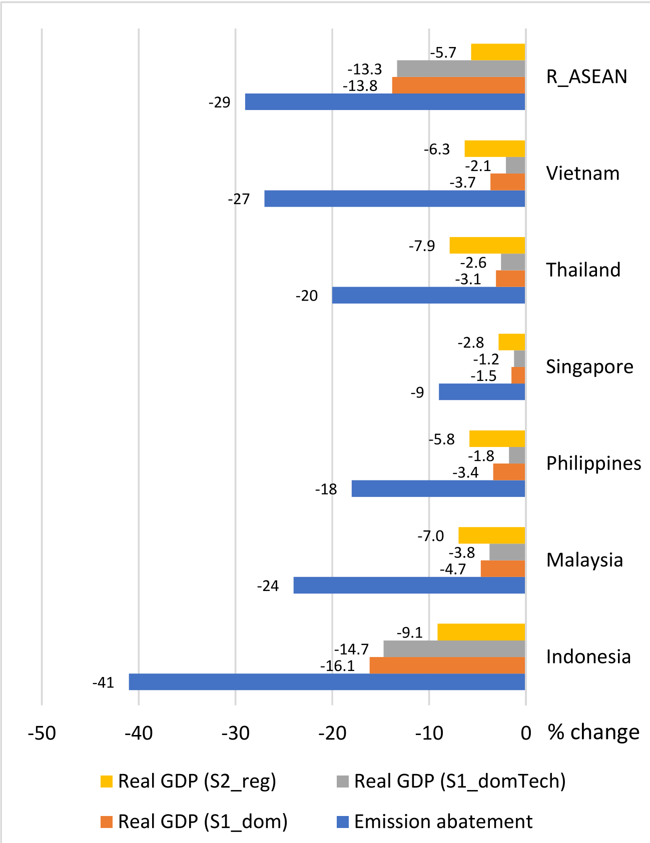

Fig. 4. Emissions reduction rates and impacts on real GDP in ASEAN countries in three scenarios (% change).

total emission levels (Table S1 in Supplement). The emissions released from production processes in Indonesia account for 30% of its total emission level (1387 $MtCO_2e$), while the emissions released from the primary factors in the 'rest of ASEAN' region account for 47% of its total emission level (218 Mt CO_2e). These facts indicate that industries in these regions need to reduce their production levels to enable high emission cuts. As a result, high economic costs are the outcomes. Another similar example refers to the case of Thailand and the Philippines. That is, Thailand aims to reduce its emission level by 20%, while the reduction rate for the Philippines is at 18%; however, Thailand only experiences a real GDP reduction by 3.1%, and the Philippines suffers a reduction by 3.4%. It is because the shares of emissions from production processes (20%) and from endowment factors (18%) in the Philippines are much higher than those in Thailand (12% and 9%, respectively) (Table S1 in Supplement).

By way of considering how existing shares of renewable energy would affect the economic costs when there are carbon prices in place, Vietnam has a much higher share of renewable energy (0.4%) compared to the share (0.02%) in Malaysia (Fig. S1 in Supplement). As a result, Vietnam has a higher emissions abatement target (−27%) compared to the target in Malaysia (−24%), but Vietnam experiences only 3.7% reduction in its real GDP while Malaysia suffers a decline of 4.7% (Fig. 4). It is also further confirmed by examining the development of the renewable energy technology that increases the shares of renewable energy. Fig. 4 shows that with the support of renewable energy technology development, all countries/regions experience lower negative impacts on their economic performance (e.g., the impacts on the real GDP) as shown in S1_domTech relative to S1_dom. When a country has a higher share of renewable energy, it will be less dependent on fossil-based energy, thus having a lower financial burden on emissions costs. Consequently, negative impacts on its economic performance are lower relative to the other countries where there are lower shares of renewable energy.

The negative economic impacts on countries' economies may however increase or decrease when these ASEAN countries move from their domestic ETS markets to the regional ETS market, where industries in these countries can trade emission permits together. It is noted that emission abatement targets and allowances of industries and countries remain unchanged when moving from domestic ETS settings to the regional ETS market. In this instance, only Indonesia and the 'rest of ASEAN' region experience lower negative impacts when moving from their domestic ETS markets to the regional ETS market. That is, the real GDP declines by 5.67% in the 'rest of ASEAN' region and by 9.1% in Indonesia in S2_reg (Fig. 4). Vietnam (−6.3%), Thailand (−7.9%), the Philippines (−5.8%), Singapore (−2.8%), and Malaysia (−7.0%), on the other hand, suffer higher real GDP reduction rates in S2_reg relative to the impacts when they carry out their domestic ETSs (Fig. 4). These impacts can also be understood by observing the carbon prices in these countries when moving from domestic ETS markets to a regional ETS market. When the ETSs are simulated domestically (Scenario S1_dom), Indonesia ($129 per tCO_2e) and the rest of ASEAN ($165) experience relatively high carbon prices compared to the carbon prices in other countries (Table 1). However, the equilibrium carbon price in the regional ETS market is only at a much lower rate of $62 per tCO2e. Hence, these two countries/regions experience lower costs on their economies.

Vietnam, Thailand, Singapore, the Philippines, and Malaysia, however, experience higher carbon prices in the regional ETS market relative to those in their domestic ETS markets. Consequently, they suffer higher negative impacts on real GDP in S2_reg compared to the impacts in S1_dom. In fact, countries (Indonesia and the 'rest of ASEAN' region) experience a lower carbon price in the regional ETS market (S2_reg) relative to the carbon prices when they only allow industries to trade permits domestically (S1_dom), these countries will become permit buyers. It is because they face lower costs in the regional ETS market to reduce their emissions levels; hence, it is better off for them to buy permits rather than contracting their economy to reduce the emissions levels. By contrast, countries (Vietnam, Thailand, Singapore, the Philippines, and Malaysia) become permit sellers because they can reduce emissions levels at lower costs. In theory, permit selling countries are also better off because at a higher carbon price ($62) compared to the prices in their domestic ETS markets, they can achieve substantially additional revenues by selling permits to other countries (i.e., Indonesia and the 'rest of ASEAN' region). However, at the same time, their economies suffer higher carbon prices. What will happen if they do not use such revenues effectively and efficiently? In the model mechanism, the balance on the current account is equal to the sum of the ordinary trade balance (equal export minus import) and net emissions trading revenue. We assume that the net permit trading revenue is used to fully compensate for the trade balance of commodities by having a fixed balance on the current account. In such a setting, the ordinary trade balance has an opposite sign compared to the net emissions trading revenue. So for permit selling countries the trade balance becomes negative and vice versa. In other words, the net permit trading revenue countries tend to move towards trade deficit by using the net permit selling revenue. The trade balance is also assumed to be maintained along with the changes in the regional income. This case shows that if countries follow such a rewarding mechanism to use the net permit trading revenue, permit selling countries will be worse off and vice versa when they move from their domestic ETS markets into a regional ETS market. The finding also indicates that not in all cases, permit selling countries will be better off. It is also noted that only the net permit trading revenue is used to offset the trade balance, while the primary permit selling revenue based on the emissions reduction target is used to transfer to households in lump-sum.

Table 1
Carbon price and the CPI.

		Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam	R_ASEAN
Carbon price ($/t$CO_2$e)	S1_dom	129	40	33	27	20	31	165
	S1_domTech	112	34	27	25	19	26	162
	S2_reg	62	62	62	62	62	62	62

4.2. Emissions trading between countries

Table 2 shows the emission trading volumes and values between regions in ASEAN when the regional ASEAN ETS is formed (Scenario S2_reg). Due to a relatively high emission reduction commitment, Indonesia needs to buy 176 MtCO_2e ($10897 million) in the regional ETS market in Scenario S2_reg to fulfil its commitment, followed by the 'rest of ASEAN' region (29 MtCO_2e or $ 1820 million). The lowest emission abatement cost country,[7] Thailand, becomes the largest permit seller (85 MtCO_2e or $5232 million) due to its possibilities to reduce large amounts of emissions compared to its emission abatement target at the equilibrium carbon price. It is also a major polluter (released 591 MtCO_2e) in the ASEAN region, enabling high permit selling volumes. Vietnam and Malaysia also contribute a surplus of 51 MtCO_2e ($3128 million) and 37 Mt$CO_2$e ($2308 million) respectively for selling to Indonesia and the 'rest of ASEAN' region in Scenario S2_reg; however, Singapore only offers 9 MtCO_2e ($576 million) for selling due to its low emission levels compared to other countries/regions.

It is noted that emissions trading between sectors in each of the three scenarios are provided in Table S2 and Table S3 in Supplement. In general, the fossil-based electricity sector is a major permit-selling sector in all countries and scenarios, while the agricultural and coal mining sectors are main permit-buying sectors. For example, the fossil-based electricity sector in Indonesia is able to sell 129 MtCO_2e to other sectors, while the agricultural and coal mining sectors need to buy 65 MtCO_2e and 58 MtCO_2e when the ETSs are implemented domestically in Scenario S1_dom. Such outcomes are because the fossil-based electricity sector has high emission levels and possibilities to replace high emission-intensive inputs with low emission-intensive inputs. On the contrary, the agricultural and coal mining sectors have high emission levels released from production processes and primary factors, leading to relatively high abatement costs. When the regional ETS is formed (Scenario S2_reg), the low emission abatement cost sector, the fossil-based electricity sector, in other countries/regions also join the trading market so that the fossil-based electricity sector in Indonesia needs to share the trading market with such a sector in other countries. As a result, the fossil-based electricity sector in Indonesia is only able to sell 65 MtCO_2 in Scenario S2_reg. Such a sector in Thailand, the Philippines, Malaysia and Vietnam can sell 19 MtCO_2e, 27 MtCO_2e, 37 MtCO_2e, and 34 MtCO_2e, respectively in Scenario S2_reg. In such a regional ETS scenario, the agricultural and coal mining in Indonesia also enjoy lower abatement costs, enabling them to buy more emission permits from other low abatement cost industries in other countries. For instance, the agricultural and coal mining sectors in Indonesia will buy 72 MtCO_2e and 65 MtCO_2e from the regional ETS market in Scenario S2_reg.

Table 2
Emissions trading among countries in Scenario S2_reg.

	Quantity (MtCO2e)	Value ($ million)
Indonesia	−176	−10897
Malaysia	37	2308
Philippines	24	1473
Singapore	9	576
Thailand	85	5232
Vietnam	51	3128
R_ASEAN	−29	−1820

Note: Negative values indicate buyers and vice versa.

4.3. Energy-related results

Pricing emissions obviously adds substantial financial burdens on major polluting sectors, as well as related industries. Fig. 5 shows the impacts on the output levels of key energy-related sectors.[8] In all regions and scenarios, the fossil-based electricity generation and coal mining sectors are the most unfavourably affected sectors. This is because the fossil-based electricity generation sector is the most emission-intensive sector. Although this sector can substitute between fossil fuel resources, it still shows major reliance on coal with high emission amounts. As a result, this sector suffers relatively high emission costs, leading to high reduction rates in its output levels. The coal mining sector experience high cuts in its output levels because all sectors switch to use non-coal energy inputs, such as natural gas and petroleum products, leading to much lower demands for coal.

The electricity transmission/service sector also experiences relatively high reduction rates in its output levels across regions and scenarios. However, magnitudes of the impact depend on the structure of the power market related to shares and growth rates of renewable power. If shares and growth rates of renewable power are high, the negative impacts on the electricity service sector will be small, and vice versa. The energy-intensive sector experiences relatively small negative impacts on its production level since this sector uses a variety of energy resources and has possibilities to substitute low emission-intensive inputs for relatively high emission-intensive inputs. In addition, this sector can also substitute electricity for fossil fuels to reduce emission cost burdens. Hence, the impacts on its production level are moderate

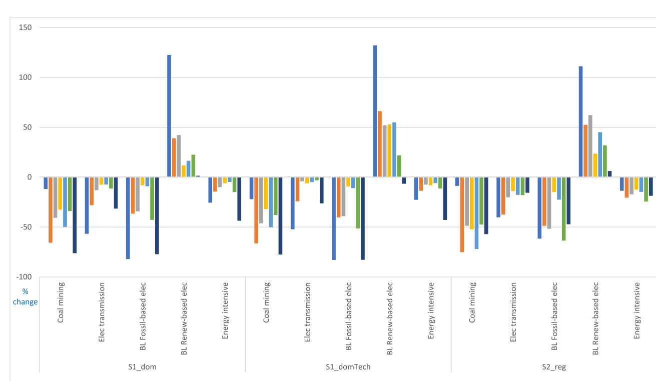

Fig. 5. Impacts on the output levels of key energy-related industries (% change).

[7] A relative comparison of emission abatement costs is always at certain levels of emission abatement targets. If the emission abatement target of a country increases, such a country may no longer be a low emission abatement cost country.

[8] Table S4 in the Supplement provides the impacts on the output levels of all sectors across scenarios.

compared to other sectors. The renewable-based electricity shows strong growth in many countries to become substitutes for fossil-based electricity. As an illustration, in the domestic ETS settings (Scenarios S1_dom and S1_domTech), the fossil-based electricity generation sectors in Indonesia and the 'rest of ASEAN' region experience the highest cuts in their output levels by 82% and 77% respectively because of high emission costs. There are only slight increases in the negative impacts on this sector's output by 83% in both regions between S1_dom and S1_domTech though S1_domTech includes 50% renewable technology improvement. This is because emission costs will only slightly decline from S1_dom to S1_domTech and fossil-based electricity accounts for major shares in total power outputs in these two regions. The negative impacts on the fossil-based electricity generation sector in Indonesia and the 'rest of ASEAN' region, substantially improve, reaching −62% and −47%, respectively in Scenario S2_reg when emission costs decline. The fossil-based electricity sectors in Malaysia, the Philippines and Vietnam experience increasing trends in the negative impacts on their output levels ranging from Scenario S1_dom to S2_reg because these sectors increase selling permits over scenarios. That is, they would reduce their output levels to have higher emission reductions. The fossil-based electricity sector in Vietnam, for example has reduced its output level from 43% to 69% over the scenarios. The renewable-based electricity in Indonesia shows the highest growth rates from 123% in S1_dom to %132 in S1_domTech. Such strong growth rates are to compensate for deep cuts in the output of fossil-based power. The renewable technology improvement scenario (S1_domTech) shows higher growth rates for renewable power due to induced technological development.

Table 3 shows the private demand for fossil- and renewable-based electricity in each region across scenarios. Since costs on emissions highly and positively relate to costs of electricity generated from emission-intensive resources (fossil fuels), the prices of fossil-based electricity will increase along with carbon prices. In regions that have high carbon prices such as Indonesia and the 'rest of ASEAN' region in Scenarios S1_dom and S1_domTech the private sector materially reduces its demand for fossil-based electricity (e.g., −83% ($3417 million) and −80% ($3290 million) in the two scenarios in Indonesia and −71% ($392 million) and −70% ($387 million) in the 'rest of ASEAN' region). The private sector in other countries will also lower its demand for fossil-based electricity, for example, by 38% ($795–$784 million) in Malaysia and Vietnam, by 34% ($555 million) in the Philippines, by 9% ($80–$332 million) in Singapore and Thailand in Scenario S1_dom. In the regional ETS scenario (S2_reg), the private sector in Malaysia, the Philippines, Singapore, Thailand, and Vietnam suffers higher fossil-based electricity prices induced by higher emission costs compared to domestic ETS scenarios. Hence, the private sector in these countries will experience strong cuts in demand for fossil-based electricity. For instance, the private sector reduces demand for fossil-based electricity by 50% ($1050 million) in Malaysia, by 51% ($836 million) in the Philippines, by 17% ($147 million) in Singapore, by 22% ($771 million) in Thailand, and by 57% ($1160 million) in Vietnam in Scenario S2_reg.

By contrast, the private sector in Indonesia and the rest of ASEAN will reduce its demand for fossil-based electricity at smaller rates (−63% or $2604 million in Indonesia and −44% or $246 million) in S2_reg compared to the reduction rates in S1_dom due to lower emission costs inducing lower increased electricity prices. The reduction rates in the demand by the private sector for fossil-based electricity in the renewable technology improvement scenario (S1_domTech) in all regions are smaller than the reduction rates in the non-technological development scenario (S1_dom). This is because of lower emission abatement costs in the technology scenario.

The private sector, on the other hand, shows increased demand for renewable-based electricity in all regions across scenarios to substitute for fossil-based electricity. The private demand for renewable-based electricity increases the most in Indonesia by 97–111% ($211–$231 million) over scenarios due to its highest reduction among ASEAN countries in the demand for fossil-based electricity. In all scenarios, the private sector however experiences net losses in overall demand for electricity in all countries because of relatively high reduction rates in demand for fossil-based electricity, which is not adequately compensated by increased demand for renewable-based power. This is also because the supplies from renewable power sectors in the regions are still relatively small compared with the fossil-based power sectors.

4.4. Macroeconomic results

Table 4 additionally shows how the ETSs affect various countries at macroeconomic levels across scenarios. Real exports and imports in all countries/regions decline at high rates. Declines in real exports are because of higher supply prices in their domestic markets, making their commodities more expensive in international markets. On the other hand, declines in real imports are due to lower production levels in their markets, which are suffering high emission costs, thereby reducing demands for goods and services sourced from both domestic and international markets. Similar to the impacts on real GDP, real imports and exports in Indonesia and the 'rest of ASEAN' region experience much smaller negative impacts in the regional ETS scenario (S2_reg) rather than in their domestic ETS scenarios (S1_dom and S1_domTech), while the impact directions are opposite in the cases of Malaysia, the Philippines, Singapore, Thailand and Vietnam. In all countries, scenarios with renewable technology improvement (Scenario S1_domTech) also show smaller negative impacts on real exports and imports compared to the cases without such technology improvement (Scenario S1_dom). Indonesia, for example, reduces its real exports from 6.6% ($18,463 million) to 16.46% ($46,061 million) across scenarios. Its real imports

Table 3
Changes in the private demand for fossil- and renewable-based electricity.

		Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam	R_ASEAN
		S1_dom						
Fossil-based	% change	−83	−38	−34	−9	−9	−38	−71
	$ million change	−3417	−795	−555	−80	−332	−784	−392
Renewable-based	% change	108	36	42	10	15	23	6
	$ million change	225	29	515	3	53	342	37
		S1_domTech						
Fossil-based	% change	−80	−34	−27	−8	−8	−33	−70
	$ million change	−3290	−707	−443	−68	−279	−671	−387
Renewable-based	% change	111	33	38	9	15	21	7
	$ million change	231	27	461	3	51	324	43
		S2_reg						
Fossil-based	% change	−63	−50	−51	−17	−22	−57	−44
	$ million change	−2604	−1050	−836	−147	−771	−1160	−246
Renewable-based	% change	101	49	63	20	45	34	6
	$ million change	210	39	770	6	154	512	40

Table 4
Macroeconomic results.

Variable	Region	S1_dom		S1_domtech		S2_reg	
		% change	$ change (million)	% change	$ change (million)	% change	$ change (million)
Real GDP	Indonesia	−16.14	−245305	−14.7	−223321	−9.13	−138791
	Malaysia	−4.68	−21856	−3.76	−17557	−6.97	−32546
	Philippines	−3.37	−14312	−1.76	−7456	−5.84	−24777
	Singapore	−1.5	−5287	−1.23	−4328	−2.82	−9955
	Thailand	−3.1	−18141	−2.57	−15044	−7.87	−46013
	Vietnam	−3.67	−12238	−2.07	−6904	−6.32	−21060
	R_ASEAN	−13.82	−24961	−13.32	−24050	−5.67	−10242
Real export	Indonesia	−16.46	−46061	−15.04	−42081	−6.8	−19045
	Malaysia	−6.05	−18911	−5.07	−15833	−9.29	−29026
	Philippines	−5.78	−6097	−3.89	−4106	−10.89	−11495
	Singapore	−4	−14122	−3.75	−13265	−6.44	−22745
	Thailand	−3.88	−13580	−3.42	−11945	−10.86	−37955
	Vietnam	−5.11	−11673	−3.37	−7707	−9.68	−22123
	R_ASEAN	−15.3	−11431	−14.79	−11050	−5.23	−3907
Real import	Indonesia	−14.89	−41200	−14.08	−38961	−10.43	−28869
	Malaysia	−5.65	−15389	−4.69	−12774	−7.93	−21574
	Philippines	−3.86	−5298	−2.37	−3251	−6.16	−8460
	Singapore	−3.77	−12548	−3.45	−11498	−5.33	−17763
	Thailand	−3.69	−12405	−3.13	−10530	−8.04	−27010
	Vietnam	−4	−10285	−2.45	−6289	−6.29	−16187
	R_ASEAN	−13.16	−9542	−12.73	−9230	−7.32	−5309
Real private consumption	Indonesia	−15.36	−133616	−14.21	−123612	−9.54	−82988
	Malaysia	−3.87	−9119	−3.21	−7564	−5.3	−12489
	Philippines	−2.72	−9065	−1.07	−3566	−4.36	−14530
	Singapore	−0.97	−1607	−0.62	−1027	−1.25	−2071
	Thailand	−2.61	−8186	−2.02	−6335	−5.18	−16246
	Vietnam	−2.89	−7677	−1.48	−3932	−3.95	−10493
	R_ASEAN	−12.14	−10977	−11.81	−10678	−6.13	−5543

Note: R_ASEAN: the rest of ASEAN.

will also decline from 9.97% ($27,602 million) to 14.89% ($41,200 million).

The real private consumption is also highly unfavourably affected across countries and scenarios. The magnitudes of the impacts also follow the levels of carbon prices in each country market. There are two main reasons for the results on the real private consumption. First, the private sector experiences higher commodity prices, particularly the electricity commodity, which includes high emission costs. When the costs decrease, the negative impacts also decline. Second, industries also reduce demand for primary factors including labour, leading to lower incomes for the private sector. Such lower income levels reduce their purchasing power. Results show that the private sector in Indonesia experiences the highest negative impacts on their consumption levels with declines by 9.54% ($82,988 million) to 15.36% ($133,616 million). The real private consumption in Singapore only experiences slight reductions by 0.62% ($1,027 million) to 1.25% ($2,071 million) due to low carbon prices. Malaysia, the Philippines, Thailand, and Vietnam experience moderate reductions in real private consumption levels compared to the reduction rates in Indonesia and the ‘rest of ASEAN’ region. The real private consumption in these four countries declines by 2.61%–3.87% in S1_dom, by 1.07%–3.21% in S1_domTech, and by 3.95%–5.3% in S2_reg.

Fig. 6 shows the emission intensity measured by the ratio of tCO_2e to GDP (in $ million). Initially, Vietnam and the ‘rest of ASEAN’ region show the highest emission intensities of 1330 and 1274 tCO_2e per $ million GDP, respectively, while the emission intensity in Singapore is the smallest (344). Over scenarios, the emission intensities in all regions will decline, indicating higher reduction rates in the emission levels rather than declines in GDP. However, such emission intensities in Vietnam and the ‘rest of ASEAN’ region are still high, ranging from 926 to 1055 in Vietnam and from 1070 to 1151 in the ‘rest of ASEAN’ region. Singapore still shows the lowest emission intensities across scenarios ranging from 296 to 319. It is noted that permit-buying regions (Indonesia and the ‘rest of ASEAN’ region) experience increases in the

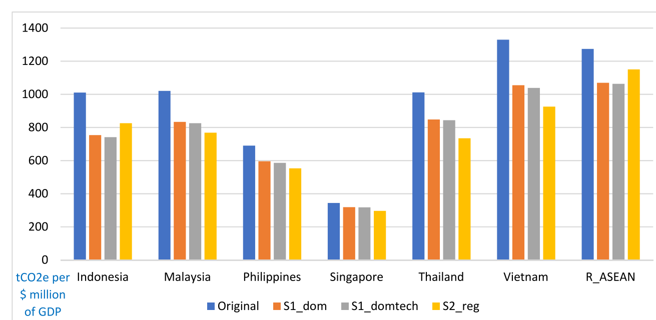

Fig. 6. Emission intensity (tCO_2e per $ million of GDP).
Note: R_ASEAN: the ‘rest of ASEAN’ region.

emission intensities when moving from their domestic ETSs (S1_dom and S1_domTech) to a regional ASEAN ETS (S2_reg) because they can emit more compared to their emission targets and buy additional permits from other countries to fulfil their commitments. On the contrary, permit-selling countries (Malaysia, the Philippines, Singapore, Thailand, and Vietnam) experience lower emission intensities in the regional ETS scenarios compared to the domestic ETS scenarios because they need to reduce their emission levels at higher levels compared to their targets in order to sell permits to Indonesia and the rest of ASEAN.

5. Discussions, recommendations and limitations

The 2030 emission targets committed by the ASEAN countries significantly adversely impact their economies, particularly the economies of Indonesia and the ‘rest of ASEAN’ region. These two regions experience relatively high carbon prices in their domestic ETS markets subject to their relatively high emission abatement targets. However, costs to their economies are much smaller when they join the regional

ASEAN ETS with Malaysia, the Philippines, Singapore, Thailand, and Vietnam. We also found that permit-selling countries do not achieve net gains compared to the impacts on their domestic ETS markets due to an inefficient recycling scheme. That is, the net permit trading revenue is used to fully offset the trade balance of commodities to have an unchanged balance on the current account. And thus, the net permit trading revenue countries tend to larger the trade deficit by using the net permit selling revenue. It is also accompanied by an assumption that the trade balance is assumed to be maintained along with the changes in the regional income. As a result, permit-selling countries are worse off while permit-buying countries are better off when moving from domestic ETS markets to a regional ETS market.

Permit-selling countries also experience lower emission intensities in the regional ETS setting compared to the emission intensities in their domestic ETS markets because they need to reduce emissions at higher levels compared to their committed targets to have surplus permits selling to other regions. The permit-buying regions show opposite outcomes in the results related to emission intensities. We also found that renewable technology improvement can help reduce reliance on fossil fuels, thereby reducing emission abatement costs. As a result, countries with renewable technology improvement achieve lower economic costs compared to the cases without such improvements.

The findings also show that fossil-based energy experiences deep cuts in their production levels, while renewable energy gains through expansions. However, increased renewable energy outputs are not adequate to offset reductions in fossil-based energy. The household sector also significantly reduces its demand for fossil-based electricity due to increased prices, while there are improvements in demand for renewable energy. However, the private sector still experiences net losses in electricity demand due to emission costs induced while fossil-based electricity is still a dominant source.

It is noted that possibilities to switch to low emission-intensive resources also affect abatement costs of countries and industries. A country with higher possibilities to switch to cleaner production technologies will be likely to experience lower costs on its economy. In the GTAP-E-PowerS model, the same industries across countries, however, have the same substitution possibilities, indicated by the same substitution parameters. It indicates that countries are not differentiated by having possibilities to substitute for 'dusty' inputs. In other words, countries in GTAP-E-PowerS apply flat technologies across the world economy. As a result, countries would not experience different impacts because of this factor. It is acknowledged as a limitation in the model because technologies are likely to be different across countries, especially between developed and low-income countries. However, when considering countries within a small region such as ASEAN, it is still reasonable to mention that technologies might not be highly different. At industrial sectors, many industries, however, have different structures and possibilities to use low emission-intensive inputs; hence, costs on industries are different as shown previously.

Additional limitation in this study refers to the assumption on renewable technology development of which we do not account for associated costs to enable such development. It is also acknowledged that it is very challenging to know explicitly how much investment each country needs to enable 50% improvement in the renewable energy input augmenting technical change. If costs were considered, positive impacts would be lower. We thus still consider it a limitation in the study to address in future studies. However, technical improvement can also be facilitated by learning-by-doing processes, which can be costless. In such a context, the assumption in this study is still reasonable. In both cases, the conclusion is still valid that renewable technology development would help countries reduce emissions abatement costs on their economies; hence, policies and additional funding to facilitate such development are desired.

Findings should also be utilised with caution. The sensitivity analysis subject to changes in elasticity of substitution parameters (Tables S5–S7 in Supplement) shows that some new sets of parameters can substantially alter the modelling results, such as the Armington elasticitiy and the elasticity of substitution between energy inputs. However, major changes are only observed when these parameters are changed substantially (e.g., by +300%), while relatively small changes in parameters (e.g., by 50%) cause no significant changes in the results. In addition, major changes in parameters may not be the case as parameters used in GTAP databases were calibrated and examined following econometric estimates. These databases and parameters have also been used widely in the literature on various topics.

6. Conclusion and policy implications

This study employs a global CGE climate change policy-focused and electricity-detailed model (GTAP-E-PowerS) to examine how the emissions trading schemes subject to the 2030 emission abatement targets affect the ASEAN economies. The analysis spreads across the three scenarios with domestic and international settings, as well as a combination of renewable technology development. This study is conducted in the context of limited existing climate change policy studies in the region and with expectation to observe how their economies are affected if they are able to form a regional emission trading market in ASEAN. We found that the regional ETS market offers lower economic costs for permit-buying regions, but not for permit-selling regions, compared to their domestic ETSs. It is because the trade balance is entirely offset by using the net permit trading revenue to keep the balance on the current account unchanged, resulting in higher level of trade deficit. The outcome is also accompanied by an assumption that the trade balance is assumed to move along with the changes in the regional income. As a result, permit-selling countries are worse off while permit-buying countries are better off when moving from domestic ETS markets to a regional ETS market.

The modelling findings also suggest that technological improvements also play key roles in lowering economic costs of climate change policies. Renewable energy shows strong expansions in their production levels, but it is still far from becoming dominant in the ASEAN region to significantly reduce economic costs of climate change policies. The private sector also increases its demand for renewable energy in all countries while lowering demand for fossil-based energy, which still experiences reductions in the overall electricity demand due to dominance of fossil-based energy. The real GDP in Indonesia would decline most under the ETS scenarios with reduction rates of 8.58% ($130,336 million) to 16.14% ($245,305 million) across scenarios.

Findings also suggest that renewable technology development and/or expansions of renewable energy production can lead to lower costs to economies when implementing a climate change policy. Thus, the ASEAN countries may need to facilitate a strong development of renewable energy by means of subsidies, tax reductions, feed-in-tariff, or inviting investments from the private sector. It is worth noting that such a finding was found in the context of negligible costs to enable technological development. If costs were considered, positive impacts would be lower. However, technology can still be improved through learning-by-doing process, which can be costless.

Regional or international ETS linkage is also a desirable option, but it is not always beneficial to all members if revenue recycling schemes are not used effectively and efficiently. Hence, future studies should identify effective revenue recycling schemes sothat all members achieve net gains compared to their own domestic ETSs, thereby encouraging more countries to join regional or international ETSs schemes to tackle climate change globally.

CRediT authorship contribution statement

Duong Binh Nguyen: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing. **Duy Nong:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Mahinda Siriwardana:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Writing – original draft, Writing – review & editing. **Hien Pham:** Conceptualization, Formal analysis, Investigation, Methodology, Resources, Validation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

We would like to confirm that we have acknowledged the funding sources. We also confirm that the material in the manuscript has not been published, is not being published or considered for publication elsewhere, and will not be submitted for publication elsewhere. The material in the manuscript, to the best of our knowledge, does not infringe upon other published material protected by copyright. Foreign Trade University, CSIRO, and the University of New England retain no ownership rights. We confirm that there are no unethical issues in publishing this manuscript in the Journal. Finally, we agree to willingly comply with all of the journal requirements.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.enpol.2023.113583.

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