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Carbon Pricing and International Competitiveness for Thailand and ASEAN*

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ABSTRACT

The main purpose of this paper is to provide an economic analysis such that policy makers may decide which carbon pricing measures, between carbon markets or Emission Trading System (ETS) and carbon taxes, would be more appropriate for Thailand based on their impacts on production, consumption, exports, imports, social welfare and international competitiveness. We find that a carbon tax measure that is jointly implemented by five ASEAN countries would be the most suitable for Thailand. This is because it can mitigate carbon dioxide emission to the target level while generating fewer negative impacts on production, consumption, exports, imports, social welfare for Thailand. It also causes less unfavorable economic effects as compared to the case of Thailand's unilateral carbon tax implementation or the case of carbon market, either unilaterally or jointly. Both carbon taxes and ETS, for the same mitigation target, does not significantly affect Thailand's international competitiveness. However, a joint carbon tax measure has fewer negative impacts on competitiveness as compared to unilateral implementation and even improves Thailand competitiveness in some sectors.

Keywords: Carbon market, emission trading system, carbon tax, carbon pricing, international competitiveness, NRCA, economic impacts, Thailand, ASEAN.

JEL Classification: Q540, F180

1. Introduction

Carbon pricing mechanisms, consisting of carbon taxes and carbon Emission Trading Systems (ETS), are carbon emission mitigation measures considered to be very effective, as they are designed to correct for market failure due to negative externality effects of carbon emission.

As of 2020, there have been 61 initiatives either to implement or to schedule carbon pricing for implementation (World Bank, 2020). This consists of 31 emission trading systems in regional, national and subnational jurisdictions, and 30 carbon taxes, primarily applied on a national level. In total, these carbon pricing initiatives cover 12 gigatons of carbon dioxide equivalent ($GtCO_2e$), or about 22 percent of global GHG emissions. Carbon taxes are used worldwide and mostly implemented in Scandinavian countries, some provinces of Canada and the United States of America. Scandinavian countries have applied carbon taxes since the 90s. On the other hand, Australia has applied a carbon tax since 2012 and has experienced huge political resistance as it has significantly impacted production costs and competitiveness. The Australian government has finally replaced the carbon tax with an ETS. These incidents suggest that appropriate carbon pricing may not be the same for each country and warrants further investigation.

Carbon pricing has been the main instrument that the Annex I countries of the Kyoto Protocol have used to fulfill their obligations. However, as the non-Annex I countries are not required to mitigate, the total emission from the latter group has been increasing drastically. The global concentration of carbon dioxide has exceeded 400 ppm since May 2013 and is still rising (Scripps Institution of Oceanography, 2013). This carbon dioxide concentration statistic is a warning signal that the average global temperature will rise closer to the threshold level of 2°C above pre-industrial levels, a threshold level which climate scientists have predicted will cause serious climate disasters.

As a consequence, negotiators from developed countries have been pressing the non-Annex I countries, especially the so-called BASIC Group[1], to start sharing the mitigation responsibility since the 15^{th} Conference of the Parties or COP 15 of UNFCCC at Copenhagen in 2009. In 2015, at the COP 21 in Paris countries adopted the Paris Agreement. The new agreement aims at strengthening the global response to the threat of climate change by keeping the global temperature rise to be below 2°C by the end of this century, and if possible, to pursue efforts to limit the temperature increase even further to 1.5°C.

However, the Climate Action Tracker has estimated that the Intended Nationally Determined Contributions (INDCs) proposed by all parties before the conference in Paris can only limit the increase of temperature to 2.7°C and there is still a significant emissions gap that need global cooperation to maintain the 2°C limit by the year 2025. The emission gap is estimated to be around 11–13 $GtCO_2e$ and is about 14–16 $GtCO_2e$ for 1.5°C (Climate Action Tracker, 2015). Even worse, the latest update released at COP 25 in Madrid on December 10^{th} 2019 indicated that most governments seem determined to continue embracing fossil fuels, and even if they met their Paris Agreement pledges, we would see a warming of 2.8°C by the end of this century (Climate Action Tracker, 2019).

The above emission gap suggests that all countries must increase their efforts in order to reach the common target. According to the Paris Agreement, each member is required to contribute to the common goal by submitting the Nationally

[1] The group consists of Brazil, South Africa, India, and China.

Determined Contributions (NDCs). Although the NDC is not a legally binding emission target, all members must report their progress toward their NDCs and revise them regularly. Developing countries, including Thailand, will therefore be pressured to put additional mitigation measures to reach higher and higher contribution targets.

According to the country's 2005 National Communication, Thailand emitted 351.3 $MtCO_2e$ and was ranked 24th globally. Emissions was amount to 5.6 tCO_2e per capita which was 71st in global rankings, rising continuously from 107th in 2000. These statistics clearly show that Thailand will be forced by international peers to submit more ambitious contributions. As a result, the country will need much stronger measures than just energy efficiency and renewable energy measures. Hence, it is inevitable that carbon pricing measures such as a carbon tax or ETS will be in the policy menu in the near future.

In order to justify whether carbon pricing should be used or not, policy makers must have sufficient information about the economic impacts of such measures. Carbon pricing internalizes the externality effects of the carbon dioxide emission back to the polluter. This in turn raises the cost of production and market price, which can cause several impacts on production, exports, imports, GDP, and the national social welfare. The additional costs can also reduce the international competitiveness of the goods being produced. As Thailand's degree of openness[2] has always been well above 100%, applying a carbon pricing policy that might affect its international competitiveness is definitely a serious economic and political issue. The main objective of this paper is, therefore, to provide the impact assessment of carbon pricing measures on important economic activities, national welfare,

[2] For instance, the degree of openness for Thailand in 2016 was 123%. See https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS

and the international competitiveness of Thailand and ASEAN.

This paper is organized as follows: section 2 provides a literature review on the impacts of carbon pricing, while section 3 describes the methodology used in this paper. Section 4 provides the results and discussion. Lastly, Section 5 concludes and summarizes the findings and policy implications.

2. Literature review

The heterogeneity of energy generation as well as the sources of CO_2 implies that conventional technology and performance standards would be infeasible, if not, excessively costly (Newell and Stavins, 2003). Therefore, it is generally agreed among economists that carbon pricing is one of the most effective instruments for CO_2 mitigation (Metcalf, 2009; Kaplow, 2010; Bowen, 2011; Baranzini et al., 2017; Borenstein et al., 2018). The efficiency of carbon pricing emerges from the incentive to abate emissions up to the marginal abatement cost. At the same time, it also induces users to seek substitutes for carbon-intensive fuels which reduce abatement costs even further by inducing carbon-friendly technological change (Newell, Jaffe, and Stavins 1999).

Although the cost effectiveness of carbon pricing is widely acknowledged among economists, there is less agreement regarding the choice of specific carbon-pricing policy measures. Some support carbon taxes (Mankiw, 2006; Nordhaus, 2007), while others prefer cap-and-trade mechanisms (Ellerman, Joskow, and Harrison 2003; Keohane, 2009). This leads to the question: how do the two major instruments to carbon pricing compare on relevant dimensions, such as the impacts on various economic aspects?

The survey done by Stavins (2019) shed light on the above question. In summary, carbon tax and ETS systems share some similar characteristics and outcomes, and in many cases are fully equivalent when they are designed in ways that make them truly comparable. A carbon tax and an ETS with auctioned permits are fully equivalent for incentives for emission reductions under no uncertainty[3]. They are very similar in terms of inducing carbon-saving innovations (Milliman and Prince 1989; Jung, Krutilla, and Boyd, 1996; Fischer, Parry, and Pizer 2003)[4], possibilities for raising revenue when ETS is implemented with auctioned permits (Goulder and Schein 2013), costs to regulated firms when revenue-raising instruments are employed (Goulder and Hafstead 2018)[5], and distributional impacts (Goulder and

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[3] Both instruments provide equivalent incentives for firms to carry out abatement until the marginal abatement costs are equal to either the carbon tax rate or the market-determined carbon price. Thus, all firms operate at the same marginal cost. In effect, both systems can achieve the same emission target at the same minimized compliant costs, summation of aggregate abatement costs, and marginal external costs.

[4] Carbon pricing can induce innovation through two channels: the abatement cost effect and the emission payment effect. For the first effect, innovation reduces the marginal abatement cost, which encourages more emission abatement under a carbon tax, while under the ETS system total emissions by definition remains constant. As a result, firms under a carbon tax system invest more for cleaner innovations. For the emission payment effect, firms under the ETS with auctioned permits can gain from the fall in permit price resulting from carbon-saving innovations. This second effect is not present under a fixed carbon tax or an ETS with free permits. The model and numerical simulation by Fischer et al.(2003) show that the overall effects of neither system dominates.

[5] The cost of a carbon tax or ETS system with auctioned permits depends on the method of revenue recycling. According to Goulder and Hafstead 2018 the net costs range from 15% with a lump-sum redistribution of revenue (rebates), 26% with recycling through rate cuts in payroll taxes, individual income taxes, or 67% with corporate income taxes.

Schein 2013)[6]. For transaction costs aspects that affect the compliance costs, the average transaction cost of the ETS system varies negatively with the initial permits, which make it distinctively different from that of the carbon tax system (Stavins, 1995). Furthermore, there can be real differences between these two approaches on the dimensions of efficiency in the presence of uncertainty (Weitzman, 1974)[7], and the different impacts of balanced technological change on carbon prices and emissions[8]. Lastly, they are significantly different for price volatility since the carbon tax fixes the price and letting the emission to vary, while the ETS system fixes the emission, thus, leaving the price volatile[9].

[6] A cap-and-trade system with auctioned permits is similar to a carbon tax from the perspective of regulated firms. Similarly, a carbon tax system with tradable tax exemptions for a specified quantity of emissions (the tax is levied only on emissions above a threshold), can mimic a cap-and-trade system with freely allocated permits.

[7] When the slope of the marginal abatement cost function exceeds that of the marginal benefit function, a carbon tax, is likely to be more efficient (smaller social losses due to resource misallocation arising from mistaken predictions of future costs) than an ETS system. However, when the opposite is true – that is, the slope of the marginal benefit function exceeds the slope of the marginal abatement cost function – then an ETS system would be more efficient.

[8] Under ETS system, reduction of marginal abatement costs due to balanced technological change decreases carbon prices, leaving aggregate emissions unchanged. In contrast, such technological change, under carbon tax system results in an increase in carbon prices, but a decrease in aggregate emissions.

[9] In the presence of economic growth which generate higher emissions, a fixed supply of permits under a ETS system (as a quantity instrument) implies that permit demand will increase and likewise the carbon price, leaving the emission fixed. The opposite is true during a recession. On the other hand, under the carbon tax system, an economic growth/recession will not change the carbon price (since the rate is fixed), but will lead to more/less emissions, respectively.

Early theoretical studies hypothesize that ambitious environmental regulation can impose significant costs, slow productivity growth, and eventually erode the international competitiveness for that country (Pethig, 1975; Siebert, 1977; Yohe, 1979; McGuire, 1982). However, the study by Jaffe et al. (1995) shows that there is relatively little evidence supporting such hypothesis. This latter study categorizes "competitiveness" into broad categories: 1) the change in net exports of certain goods, 2) the degree of relocation of production of pollution-intensive goods from countries with stringent environmental regulations toward those with less, and 3) the degree of offshore investment by countries with carbon pricing towards those with less or no carbon pricing.

The empirical result regarding the change in net exports is not conclusive: some find negatively correlated relationships between net exports and environmental compliance costs (Kalt, 1988), some discover that they are insignificantly correlated (Tobey, 1990; Grossman & Krueger, 1993). For the second indicator of competitiveness, several studies indicate that pollution-intensive industries have shifted away from developed countries toward developing countries, although the observed magnitude of changes are small (Low & Yeats, 1992; Robinson, 1988). Lastly, for the shift in foreign investment indicator, the evidence indicates that investment migration to less stringent environment regulation in developing countries is weak (Leonard, 1988; Bartik, 1989; Friedman et al., 1992).

More recent direct studies on carbon pricing such as Siegmeier, Mattauch and Edenhofer (2018) have found evidence which opposes the conventional belief that strict environmental measures inevitably lead to deindustrialization. The conclusion aligns with the work by Linus Mattauch which explains that even though carbon pricing may reduce the economic rents of fossil fuel, it induces the transfer of capital to other more productive industries. Moore, Großkurth, and Themann (2018) studied the impacts of the EU ETS and found that carbon pricing did not devalue the asset bases of the multinational enterprises in the EU, but actually increased their average value by 12.1%. In addition, Calel and Dechezleprêtre (2016) have found that companies that were regulated by the EU ETS have increased their low carbon innovation (measured by the number of patents) by 10% without reducing other innovation levels. The Executive Briefing of Carbon Pricing Leadership Coalition (June 2016) also concluded that carbon pricing measures do not affect competitiveness. The evidence is clear, since Norway, Sweden, Switzerland, France, and British Columbia (a province of Canada) have all been using carbon pricing without negative effects to either their industries or economic growth. On the contrary, British Columbia has been using carbon tax since 2008 together with tax revenue rebate to mitigate the burdens of personal income and corporate income taxes. This particular measure successfully reduced emission by 15% from "business as usual" (BAU). British Columbia still grew at 12.4% during 2007–2014, higher than the average Canadian growth rate. It even created 68,165 new clean jobs during 2010–2014, and increased 200 new clean technology firms and generated 1.7 billion Canadian dollars per annum (UNFCCC, 2019).

Impact studies for ASEAN countries are also available. For the individual ASEAN country case, for example, Tantivasadakarn et. al. (2008), Wattanakuljarus and Wongsa (2011), Kumsup et. al. (2014), Sutummakid et. al. (2015), and Puttanapong et. al. (2014) studied Thailand. For other ASEAN country case, there is Corong (2008) on the Philippines, Coxhead, Wattanakuljarus and Chan (2013) on Vietnam, and Yusuf and Resosudarmo (2015) on Indonesia. At the multi-country level case, work was done by Nurdianto and

Resosudarmo (2016). The result from these works consistently show that carbon pricing is an effective instrument for carbon mitigation and there are slight consequential costs on economic variables and social welfare. However, none of these papers have addressed the issue of international competitiveness which is the knowledge gap that this paper aims to bridge.

3. Methodology and the model

3.1 The model

In order to evaluate the impact of a carbon tax on several macroeconomic variables, especially international competitiveness, this paper uses a general equilibrium model called GTAP-E version 9 which is an extension of the GTAP model, the Global Trade Analysis Project (Hertel, 1997), by Burniaux and Truong (2002) and revised by McDougall and Golub (2007). It is a computable general equilibrium model, based on an economic database of 140 countries, which each has 57 production sectors, equipped with the capability to calculate the impact of carbon pricing measures on production, consumption, exports, imports, GDP, and welfare. More importantly, since it was originally designed as a trade analysis model, we can use the impacts on trade flows to further calculate the changes in international competitiveness. The model assumes each country or group of countries has a representative household that maximizes an aggregate utility function. The household receives income from selling factors of production (unskilled labor, skilled labor, capital, land, and natural resources) to the firms. The household's net income after taxes is divided into three parts: consumption, buying government provided goods, services, and savings. Demand from the government sector is governed by the Cobb-Douglas function while the household demand takes the form of constant difference of elasticity functions. On the production side, the model assumes a perfectly competitive market structure for every sector. Each firm maximizes profit and receives normal profit in the long run. Technology is assumed to behave according to nested Leontief and constant elasticity of substitution (CES) production functions. There are two global service sectors. The first is the international transport sector, which provides international transportation and links the FOB and CIF values[10]. The second are global financial services that link world savings and investment.

The GTAP-E model extends the standard GTAP model that incorporates a more detailed specification of the energy sectors and related carbon emission. Goods and services are produced via nested-CES functions by combining value-added-energy with other intermediate inputs which consist of both domestic and foreign sources. Value-added-energy is the combination of natural resources, land, skilled labor, unskilled labor, and capital-energy composite, where energy types are substitutable according to the elasticity of substitution of energy. Non-electricity energy consists of coal and non-coal (gas, oil, petroleum products).

Government expenditure in GTAP-E model is governed by nested-CES functions that combines energy composites and non-energy composites. Household expenditure also consists of energy composites and non-energy composites, but its behavior is given by the constant-difference of elasticities (CDE) function.

This paper classifies countries into 17 countries or regions: The United States (USA), European Union 27 (EU27), Eastern Europe and former Soviet Union (EEFSU), Japan (JPN), Other Annex 1 countries (RoA1), Net energy

[10] FOB stands for Free on Board and CIF stands for Cost, Insurance and Freight.

exporting countries (EEx), China (CHN), India (IND), Thailand (THA), Indonesia (IDN), Malaysia (MYS), the Philippines (PHL), Singapore (SGP), Vietnam (VNM), Cambodia and Laos (Khm_Lao), the rest of ASEAN (Oth_ASEAN), and the rest of the world (ROW). For the product classification, we group goods and services into 18 groups: Rice paddies and processed rice (Rice), oil seeds (OilSeed), sugar cane and sugar (Sugar), non-rice primary agriculture, forestry, and fishery (Oth_agr), coal mining (Coal), crude oil (Oil), natural gas extraction, gas manufacture and distribution (Gas), petroleum products (Oil_pcts), electricity, food industries besides rice (Food_ind), chemical, rubber, and plastic products (CRP), energy-intensive industries beside CRP (En_Int_ind), automobile and parts (Auto_ind), electronic equipments (Electronic_ind), machinery and equipment (Machinery_ind), other industries (Oth_ind), transport services (Transport), and other services (Oth_ser).

3.2 Scenarios

To analyze the impacts of the carbon pricing measure, this paper assesses the impact in four scenarios: 1) unilateral ETS by Thailand (UETS), 2) unilateral carbon tax by Thailand (UCTax), 3) Joint ETS by ASEAN5 (JETS), and 4) Joint carbon tax by ASEAN5 (JCTax). The term “unilateral” used here means Thailand is the only country that uses the carbon pricing measure, either the ETS or the carbon tax to meet the emission reduction by 20% from her BAU emission[11]. The

[11] According to Thailand’s Nationally Determined Contribution (NDC), Thailand intends to reduce her greenhouse gas emissions by 20 percent from the projected BAU level by 2030. The same 20% emission reduction target is, therefore, chosen here in this study to mimic the submitted target

term "joint" on the other hand means five ASEAN countries: Indonesia, Malaysia, Singapore, the Philippines, and Thailand, jointly use the carbon pricing measure to meet the 20% reduction from the BAU emission level of each country. The same target for all ASEAN members is chosen here for consistency and comparison purpose to the unilateral case.

The implementation of the ETS in the GTAP-E model is achieved by setting a 20% cap on CO_2 from BAU in three sectors, namely electricity, energy intensive industries, and other industries. In order to make the impact assessment comparable for carbon tax scenarios, the tax is charged on all energy sectors: i.e., Coal, Oil, Gas, Oil_pcts, and Electricity, such that the CO_2 emission is reduced by 20%.

The shock to the GTAP-E model in each scenario will generate new general equilibrium endogenous values. Then, the percentage changes of production, exports, imports, GDP, and welfare of each scenario compared with the based case are presented and analyzed. In addition, the exports value of each product or service for the BAU and each scenario are used to calculate the international competitiveness. The index used in this paper is described in section 3.3. Both overall economic and competitiveness results are presented in Section 4.

3.3 Indexes for international competitiveness

Conventionally, international trade economists often employ Balassa's Revealed Comparative Advantage Index (RCA) as a tool to calculate the degree of competitiveness and the index can be calculated from the following formula (see Balassa, 1965)[12]. Although the RCA index is relatively simple

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although the mitigation tools proposed in the NDC are mainly energy efficiency improvement and renewable energy.

[12] The Balassa index is given by $RCA_{ij} = (X_{ij} / X_i) / (X_{wj} / X_w)$ where the variables in the formula are defined the same way as those given in

to be calculated and interpreted, it is not appropriate to be used for cross-country comparison[13]. Therefore, in this study, we use the Normalized Revealed Comparative Advantage (NRCA)[14] which can be calculated by[15]

$$NRCA_{ij} = \left(X_{ij}/X_w - X_{wj}X_i/X_wX_w\right) \qquad (1)$$

Where X is the export value of goods, i stands for the country index, j is the goods index, and w represents the export value at the world level. Hence, X_{ij} is the export value of goods j from country i, while X_{wj} is the total world export value of goods j, and X_w is the total world export value of all goods.

It is possible to prove that the $NRCA_{ij}$ has a range of values between -2.5 and 2.5 with a zero midpoint value, which means that country i neither has comparative advantage nor disadvantage in goods i. A positive or negative value means country i has a comparative advantage or disadvantage in that goods, respectively. (Yu et al., 2009). This index is adopted here instead because when the value of NRCA for a product increases or its comparative advantage rises, the remaining

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equation (1). The RCA index is very easy to be interpret; i.e., if $RCA_{ij} > 1$, it means country i has a comparative advantage[12] in product j and if $RCA_{ij} < 1$ it means country i has a comparative disadvantage in product j.

[13] The maximum value of RCA_{ij} depends on the value of X_w/X_{wj}, which vary across products and time. This dependence on size variability creates inconsistent interpretations for cross country comparison. See details in Benedictis & Tamberi, 2002.

[14] Yu, Cai & Leung (2009) "The normalized revealed comparative advantage index," *Annals of Regional Science*, Vol. 43, 267-282.

[15] For actual applications, Yu et al. (2009) advises to multiply the formula by 10,000. This is because the formulae normalize the Balassa's RCA index by dividing it with world total export value, which is generally very large with respect to each product value of each country. Without the multiplication of 10,000, the calculated index will be very small.

products' comparative advantages will always fall. This is due to the fact that the summation of all products' NRCAs always equal to zero. As a result, the index is appropriate for international competitiveness comparison. Moreover, the index is not dependent on the level of classification details or the selection of countries used for comparison[16].

4. Impact assessment of carbon pricing

The results in this section consists of five parts. The impact on changes in production will be presented in section 4.1, followed by the impact on exports and imports in section 4.2, GDP in section 4.3, welfare in section 4.4, and competitiveness in section 4.5. Note that due to the multi-dimension nature of the results involving four scenarios, 18 sectors, and 17 countries or regions, it will take too much space to present all permutation of cases. Hence, for the sake of brevity, results related to production (4.1), imports and exports (4.2), welfare (4.4), and the impact on competitiveness pattern will be presented only for Thailand. However, for the impacts on GDPs and the initial competitiveness patterns in ASEAN, the result for all ASEAN members will be presented.

From the database of GTAP-E, in 2011, Thailand emitted 242.197 $MtCO_2$, which were mainly from the petroleum products (103.233 $MtCO_2$), followed by coal (71.303 $MtCO_2$) and natural gas (67.584 $MtCO_2$). These emission levels will be treated as the emission under the BAU. As mentioned earlier, we simulated four scenarios of carbon pricing measures 1) Unilateral ETS by Thailand (UETS), 2) Unilateral carbon tax by Thailand (UCTax), 3) Joint ETS by ASEAN5 (JETS), and 4) Joint carbon tax by ASEAN5 (JCTax). In the following,

[16] See details in Sanidas & Shin (2010).

Table 1 to Table 5 summarizes the assessment impacts on production, imports, exports, GDPs, and welfare, respectively.

4.1 Production

It is clear from Table 1 that the production of the energy sectors and the carbon-intensive sectors are affected the most by carbon pricing measures. Regardless of which scenario of carbon pricing, Coal, Gas, Electricity, Oil_pcts, Transport, En_Int_ind are among the sectors the has the highest negative percentage changes. Note that carbon pricing does not always negatively affect all sectors. In fact, production of many sectors, such as Electronic_ind, Machinery_ind, Food_ind, Sugar, have been increased for all scenarios. The increase comes from the general equilibrium adjustment of the economy. As some industries are shrunk by the relatively higher costs, the resources released by these industries flows to other remaining industries that have higher profits, causing them to expand until every industry has normal profits in the long run again. However, the overall production level for all sectors are declined for all scenarios ranging from -0.01% to -2.52%. Notice also that the carbon taxes, both UCTax and JCTax, generate less negative impacts on production than the ETSs.

Table 1. Comparing the impact of ETS and Carbon Tax on Production by sectors for 20% CO_2 emission reduction

Sectors	(1) UETS (%)	(2) JETS (%)	(2)–(1) (%)	Sectors	(3) UCTax (%)	(4) JCTax (%)	(4)–(3) (%)
Coal	-28.79	-22.22	6.57	Coal	-82.84	-84.22	-1.38
Gas	-21.91	-23.26	-1.35	Electricity	-14.44	-14.30	0.14

Sectors	(1) UETS (%)	(2) JETS (%)	(2)–(1) (%)	Sectors	(3) UCTax (%)	(4) JCTax (%)	(4)–(3) (%)
Electricity	-16.55	-16.3	0.25	Gas	-13.66	-13.84	-0.18
Transport	-16.09	-15.54	0.55	En_Int_ind	-13.06	-12.61	0.45
Oil_pcts	-8.76	-15.45	-6.69	Transport	-6.25	-6.08	0.17
En_Int_ind	-8.17	-5.8	2.37	Oil_pcts	-2.62	-2.78	0.07
Oil	-4.12	-5.4	-1.28	Auto_ind	-0.53	-0.71	-0.16
Auto_ind	-1.07	-1.04	0.03	Oth_ser	-0.47	-0.46	-0.18
OilSeed	-1.02	0.08	1.10	Rice	-0.26	-0.32	0.01
Rice	-0.76	-0.27	0.49	OilSeed	0.13	0.15	-0.06
Oth_ser	-0.71	-0.65	0.06	Oth_agr	0.24	0.24	0.02
Oth_agr	-0.28	0.2	0.48	Food_ind	0.76	0.73	0.00
Sugar	0.15	1.76	1.61	Sugar	0.76	0.73	-0.03
Food_ind	0.16	1.77	1.62	Oth_ind	1.34	1.33	-0.03
Oth_ind	1.74	4.02	2.28	Machinery_in	1.64	1.39	-0.01
Machinery_in	2.65	5.97	3.32	Oil	1.71	1.46	-0.25
CRP	3.27	-11.65	-14.92	CRP	3.10	3.28	-0.25
Electronic_i	5.37	10.24	4.87	Electronic_i	3.56	3.57	0.18
All sectors	-1.78	-2.52	-0.74	All sectors	-0.01	-0.01	0.01

4.2 Exports and Imports

For exports, Table 2 shows that the impact of carbon pricing on exports is similar to the case of production. Energy sectors and energy intensive sectors; i.e. Gas, Electricity, Transport, are most negatively affected as their production costs increase relatively faster than those less energy intensive sectors. However, exports of Coal and Oil increase since the carbon pricing dampens the local demand and causes higher net returns for exports. Exports of sectors that are labor intensive; e.g., Electronic_ind and Auto_ind, increase since by the reallocation of resource as mentioned in the production case.

The patterns are quite similar for all scenarios, however, in most cases the unilateral measures, both ETSs and carbon taxes, have more negative impacts on exports than the joint measures as shown by the changes of exports for all sectors; e.g., -8.77% for UETS and 0.25% for JETS. Notice also that for most sectors that exports decreased, the carbon taxes generally have less negative impacts than those of the ETSs.

Table 2. Comparing the impact of ETS and Carbon Tax on Exports by sectors for 20% CO_2 emission reduction

Sectors	(1) UETS (%)	(2) JETS (%)	(2)–(1) (%)	Sectors	(3) UCTax (%)	(4) JCTax (%)	(4)–(3) (%)
Gas	-167.30	-122.51	44.79	Electricity	-100.38	-97.47	2.91
Electricity	-87.64	-125.23	-37.59	Gas	-19.49	-22.46	-2.97
Transport	-28.15	-32.69	-4.54	En_Int_ind	-19.08	-18.44	0.64
Oil_pcts	-13.25	-4.09	9.16	Transport	-12.45	-12.06	0.39
En_Int_ind	-11.77	-9.05	2.72	Sugar	-5.26	0.00	5.26
Sugar	-8.69	0.00	8.69	OilSeed	-1.74	-1.74	0.00
OilSeed	-3.29	-5.16	-1.88	Rice	-0.42	-0.53	-0.11
Rice	-0.93	-0.48	0.45	Oth_agr	0.20	0.20	0.00
Oth_agr	-0.47	-0.77	-0.30	Oil_pcts	1.22	-0.37	-1.59
Machinery_in	-0.07	7.81	7.88	Food_ind	1.26	1.20	-0.06
Food_ind	0.42	3.14	2.72	Machinery_in	2.42	2.09	-0.33
Oil	0.60	22.91	22.31	Auto_ind	3.00	2.55	-0.45
Oth_ind	2.56	10.22	7.66	CRP	3.58	3.75	0.17
Auto_ind	2.79	6.16	3.37	Oth_ind	3.70	3.64	-0.06
Oth_ser	3.81	12.45	8.64	Electronic_i	3.82	3.84	0.02
CRP	4.78	-13.70	-18.48	Oth_ser	4.61	4.67	0.06
Electronic_i	7.29	10.88	3.59	Oil	9.72	10.03	0.31
Coal	8.04	26.65	18.61	Coal	47.28	38.69	-8.59
All sectors	-8.77	0.25	9.02	All sectors	0.91	0.85	-0.06

Table 3 presents the impact of carbon pricing on imports, which shows somewhat opposite patterns as the export side. For example, Coal and Oil imports decrease while Electricity and Transport increase. The impact on country level imports for all scenarios are negative. The carbon taxes generally also have fewer negative impacts on imports than those of the ETSs.

Table 3. Comparing the impact of ETS and Carbon Tax on Imports by sectors for 20% CO_2 emission reduction

Sectors	(1) UETS (%)	(2) JETS (%)	(2)–(1) (%)	Sectors	(3) UCTax (%)	(4) JCTax (%)	(4)–(3) (%)
Coal	-19.89	-19.88	0.01	Coal	-28.54	-0.36	28.18
Oil_pcts	-14.44	-20.81	-6.37	Oil_pcts	-5.55	-0.29	5.26
Oil	-9.76	-17.55	-7.79	Oil	-3.56	-0.06	3.50
Gas	-9.08	-13.8	-4.72	Gas	-3.54	0.24	3.78
Machinery_in	-4.16	-5.34	-1.18	Machinery_in	-2.78	-0.08	2.70
Oth_ser	-2.97	-5.41	-2.44	Oth_ser	-2.16	-0.01	2.15
Oth_ind	-2.88	-4.55	-1.67	Oth_ind	-1.91	-0.02	1.89
Auto_ind	-2.42	-3.07	-0.65	Auto_ind	-1.44	-0.01	1.43
Food_ind	-0.08	-0.17	-0.09	Food_ind	0.02	0.06	0.04
CRP	0.45	-1.98	-2.43	Rice	0.15	-0.21	-0.36
OilSeed	0.57	1.89	1.32	CRP	0.29	-0.01	-0.30
Rice	0.67	-0.36	-1.03	Oth_agr	0.52	-0.02	-0.54
Oth_agr	0.91	0.89	-0.02	OilSeed	0.76	-0.01	-0.77
Electronic_i	1.30	3.57	2.27	Electronic_i	0.86	0.11	-0.75
En_Int_ind	1.43	3.04	1.62	En_Int_ind	1.23	-0.03	-1.26
Sugar	2.19	3.69	1.5	Sugar	1.35	-0.02	-1.37
Transport	6.66	5.8	-0.87	Transport	2.12	-0.13	-2.25
Electricity	40.94	40.85	-0.09	Electricity	29.22	0.41	-28.81
All sectors	-2.34	-3.93	-1.59	All sectors	-1.23	-0.03	-0.03

4.3 Gross Domestic Products

Table 4. Comparing the impact of ETS and Carbon Tax on GDPs by countries for 20% CO_2 emission reduction

Countries	(1) UETS (%)	(2) JETS (%)	(2)–(1) (%)	(3) UCTax (%)	(4) JCTax (%)	(4)–(3) (%)
USA	0.001	0.004	0.003	0.0003	0.001	0.001
EU27	0.002	0.017	0.015	0.0012	0.006	0.005
EEFSU	-0.005	-0.024	-0.019	-0.0024	-0.023	-0.021
JPN	0.001	0.012	0.011	0.0004	0.005	0.005
RoA1	0.001	0.003	0.002	0.0003	0.002	0.001
EEx	-0.001	-0.008	-0.007	0.0000	-0.002	-0.002
CHN	0.001	0.004	0.003	0.0005	0.002	0.002
IND	0.002	0.026	0.024	0.0013	0.011	0.009
THA	-0.306	-0.447	-0.141	-0.1627	-0.165	-0.003
IDN	-0.002	-0.099	-0.097	-0.0018	-0.02	-0.019
MYS	-0.007	0.43	0.437	-0.0032	0.186	0.189
PHL	-0.002	-0.106	-0.104	-0.0012	-0.041	-0.04
SGP	0.001	-0.064	-0.065	0.0001	-0.019	-0.019
VNM	-0.007	-0.067	-0.06	-0.0038	-0.02	-0.016
Khm_Lao	0.004	0.029	0.025	0.0154	0.022	0.006
Oth_ASEAN	-0.024	-0.041	-0.017	-0.009	-0.011	-0.002
ROW	0.002	0.008	0.006	0.001	0.003	0.002
World	-0.001	0.004	0.005	-0.0003	0.002	0.002

4.4 Welfare

Table 5 summarizes the impact of carbon pricing on welfare. The welfare change for Thailand in all scenarios is negative, ranging from -US$467.18 million to -US$745.79

million. According to GTAP-E, it is possible to disaggregate the welfare change in to three effects: i.e., Allocative efficiency effect, Term of trade effect, and Investment-saving effect. As shown in the table, the main reason for net welfare losses comes from the large negative impact of the allocative efficiency effect, ranging from -US$1,058.91 million under the UETS and -US$1,545.44 million under the JETS. This effect is generated by the reallocation of resources away from the BAU market equilibrium. This effect under the JETS scenario has the highest negative value. Both ETS scenarios generate positive impacts on welfare via the term of trade effect and the investment-saving effects. However, they are not sufficient to compensate and bring the total welfare to be positive.

Note that under perfect competition and no externality problems, the initial BAU market equilibrium is supposed to allocate resources in the most efficient way. When we impose ETS or carbon taxes to shock the market, there will be losses in efficiency, which is captured by the negative value of the allocative efficiency effect. However, when the externalities from CO_2 emission are present, the allocative efficiency should be canceled by the reduction of the external cost, which can bring the net effect to positive provided that the savings from external costs are sufficiently large.

Both carbon tax scenarios have less negative allocative efficiency, -US$562.54 Million under the UCTax and -US$571.47 million under the JCTax. Their corresponding terms of trade effects are both negative; the investment-saving effects are positive, but quite smaller. Hence, the total welfare changes are also negative: -US$564.71 million, -US$590.57 million, respectively.

Table 5. Comparing the impact of ETS and Carbon Tax on Thailand Welfare for 20% CO_2 emission reduction

Unit: US million

Countries	(1) UETS	(2) JETS	(2)-(1)	(3) UCTax	(4) JCTax	(4)-(3)
Allocative Efficiency	-1,058.91	-1,545.44	-486.53	-562.54	-571.47	-8.93
Term of Trade	537.32	708.05	170.73	-41.29	-54.95	-13.66
Investment-Savings	54.4	91.6	37.20	39.12	35.85	-3.27
Total welfare changes	-467.18	-745.79	-278.61	-564.71	-590.57	-25.86

4.5 International competitiveness

Table 6. The Normalized Revealed Comparative Advantage Indexes (NRCA) of ASEAN countries by sectors in 2011 for the BAU case

Sectors	Thailand (THA)	Indonesia (IDN)	Malaysia (MYS)	The Philippines (PHL)	Singapore (SGP)	Vietnam (VNM)	Cambodia &Laos (Khm_Lao)	Other ASEANs
Electronic_i	9.35	-3.79	27.25	9.95	25.22	1.39	-0.48	-0.68
CRP	8.28	2.13	1.13	-2.66	3.41	-2.99	-0.51	-0.86
Food_ind	6.59	9.05	9.09	0.50	-4.55	1.88	-0.21	-0.22
Rice	3.27	-0.11	-0.14	-0.03	-0.18	1.55	0.07	0.09
Transport	2.08	-2.24	-0.23	0.61	1.35	-1.47	0.19	-0.17
Auto_ind	1.59	-5.53	-6.87	-1.77	-9.20	-3.03	-0.43	-0.62
Sugar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity	-0.32	-0.31	-0.36	-0.10	-0.43	-0.09	0.00	-0.02
OilSeed	-0.46	-0.37	-0.39	-0.13	-0.54	-0.18	-0.02	-0.01
Oil_pcts	-0.50	-3.70	-2.55	-1.12	15.35	-1.86	-0.24	-0.35
Oth_agr	-0.87	0.04	-1.71	0.67	-3.21	2.09	0.22	0.91
Coal	-0.87	14.99	-0.84	-0.19	-1.00	0.37	-0.04	-0.06
Machinery_in	-1.45	-8.92	-3.53	0.02	2.48	-2.58	-0.88	-1.22
Gas	-1.59	5.25	2.99	-0.44	-1.85	-0.62	0.00	2.95
Oth_ind	-1.94	5.08	-7.07	-1.75	-15.56	12.48	3.05	-0.28

Sectors	Thailand (THA)	Indonesia (IDN)	Malaysia (MYS)	The Philippines (PHL)	Singapore (SGP)	Vietnam (VNM)	Cambodia &Laos (Khm_Lao)	Other ASEANs
En_Int_ind	-4.76	2.02	-4.63	0.23	-10.52	-2.31	0.11	-0.62
Oth_ser	-8.77	-10.72	-6.68	-1.16	10.44	-4.13	-0.36	-0.84
Oil	-9.64	-2.88	-5.46	-2.63	-11.22	-0.48	-0.48	2.00

Source: Calculated from GTAP-E Version 9 by NRAC formula in equation (2)

The analysis in this part is based the calculation of the NRCA index given in equation (2) (see section 3.3) using the value of exports in year 2011 provided in GTAP-E. Note that a positive $NRCA_{ij}$ value implies that country i has a comparative advantage in goods j and the negative value implies that it has a comparative disadvantage in that goods. The calculated result is provided in Table 6.

Competitiveness Patterns in ASEAN

The sectors of the NRCA index in the Table 6 is sorted by Thailand's competitiveness from the highest to the lowest value. As expected from the Heckscher-Olin Theorem, the sectors that Thailand has comparative advantages are the ones that are labor intensive or natural-resource intensive since Thailand is considered a labor and natural-resource abundant country. The sectors that are ranked highest are, for instance Electronic_ind (9.35), CRP (8.28), Food_ind (6.59), Rice (3.27), Transport [17] (2.08) and Auto_ind (1.59). On the opposite end, the sectors that Thailand has the most comparative disadvantages are Oil (-9.64), Oth_ser (-8.77),

[17] The main sub sector that has the comparative advantage is air transport, which is used most by the tourism industry. However, GTAP-E does not classify tourism as a separate sector.

En_Int_ind [18] (-4.76), Oth_ind (-1.94), Gas (-1.59), and Machinery_ind (-1.45). Notice that these products intensively use Thailand relatively scarce resources, namely capital and fossil fuel.

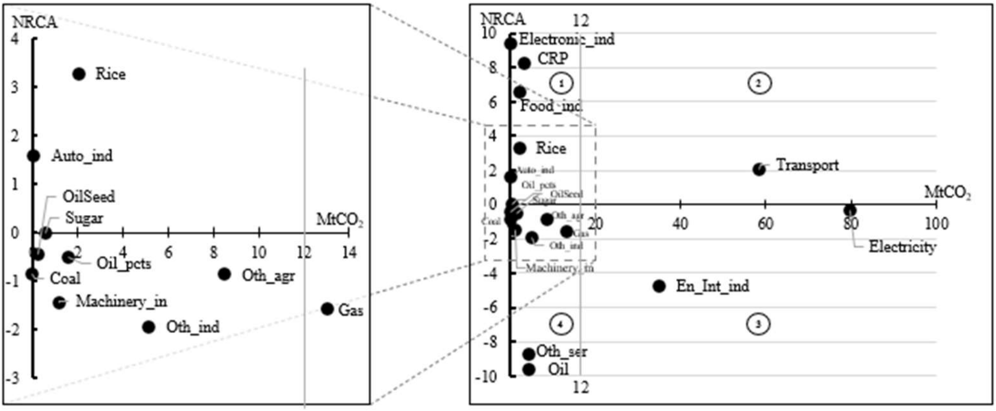
Table 6 also shows other ASEAN countries pattern of competitiveness. For instance, Indonesia has the highest NRCA in Coal (14.99) which is also the highest in ASEAN followed by Food_ind (9.05) and Gas (5.25). Malaysia has the highest NRCA in Electronics (27.25), which is also the highest value in the table. It is followed by Food industry (9.09) and Gas (2.99). For Singapore, it has many competitive sectors, such as Electronic_ind (25.22), Oil_pcts (15.35), Oth_ser (10.44), and CRP (3.41). The Philippines has relatively only one competitive sector which is Electronic_ind (9.95). The sectors that Vietnam has comparative advantages are Rice (1.55), and Electronic_ind (1.39) For Cambodia and Laos, their competitiveness lie in Oth_ind (3.05). Finally, the rest of ASEAN, Myanmar and Brunei are competitive in Gas (2.95) and Oil (2.0). Note that the comparative advantage patterns of ASEAN countries also conform with the prediction of the Heckscher-Olin Theorem, which stipulates that a country will have a comparative advantage in a product that intensively uses its abundant factor.

Competitiveness Patterns in Thailand

Figure 1 provides a snapshot, in 2011, of each sector's relative positions of NRCAs and CO_2 emission. For example the Transport sector's coordinate is plotted on the right panel at 58.29 $MtCO_2$ and 2.08. The left panel enlarge the dense cluster near the origin to show the details.

[18] They include cement, iron and steel, and other metals.

Figure 1. Thailand's competitiveness and CO_2 emission by sectors



Sources: NRCAs from Table 6; CO_2 emission from GTAP-E Version 9.

To better understand Thailand's competitiveness pattern in relation to the level of carbon emission, we chose the average emission of about 12 $MtCO_2$ as a border line between low carbon-intensive and high carbon-intensive sectors, then combine this with the zero value of NRCA to divide Figure 1 into 4 quadrants, with four combinations of characteristics. The 1st quadrant contains sectors that Thailand initially has comparative advantage and emits relatively low carbon emissions i.e., low carbon-intensive. The sectors in this group are Electronic_ind, CRP, Food_ind, Rice, and Auto_ind. Due to their low carbon emissions, we should expect these sectors to remain competitive after Thailand imposes carbon pricing measures, especially the first three sectors with high NRCAs. The 2nd quadrant represents the sector that is also initially competitive, but are relatively carbon intensive. Transport is the only one sector in this group. Carbon pricing measures should decrease its competitiveness drastically, but it may still remain competitive. The 3rd quadrant contains sectors that are neither initially competitive nor relatively low carbon-intensive; hence their comparative disadvantage positions should be severely worsened by the carbon pricing measures. Sectors in this group are Electricity, En_Int_ind, and Gas. Finally, the sectors in the 4th quadrant are those that are not initially competitive but have low carbon emissions. Carbon pricing measures should mildly worsen this group's comparative disadvantage positions. Sectors in this last group are Sugar, OilSeed, Oil_pcts, Coal, Machinery_in, and Oth_ind. With these four group classifications, we will present an example of the impact of unilateral ETS under UETS scenario on both NRCAs and CO_2 emission in the next subsection.

Impacts of Carbon Pricing on Thailand's Competitiveness: an example

Recalling that all sectors in the 1st quadrant of Figure 2 have comparative advantages and are low carbon-intensive, it is clear that after Thailand imposes unilateral ETS, all sectors in this group are induced to emit less CO_2 as indicated by the respective arrows pointing leftward. Note that longer arrows denote higher CO_2 mitigation. Since both CRP (chemical, rubber, and plastic products) and Food_ind are more carbon-intensive than others, their arrows are relatively longer. The arrows of CRP and Auto_ind also point upward which means their competitiveness actually improved. Arrows of the remaining sectors in the group, on the other hand, slightly point downward, but all the arrow tips are still positive, implying that these sectors can maintain their comparative advantage, as expected, after the ETS is used.

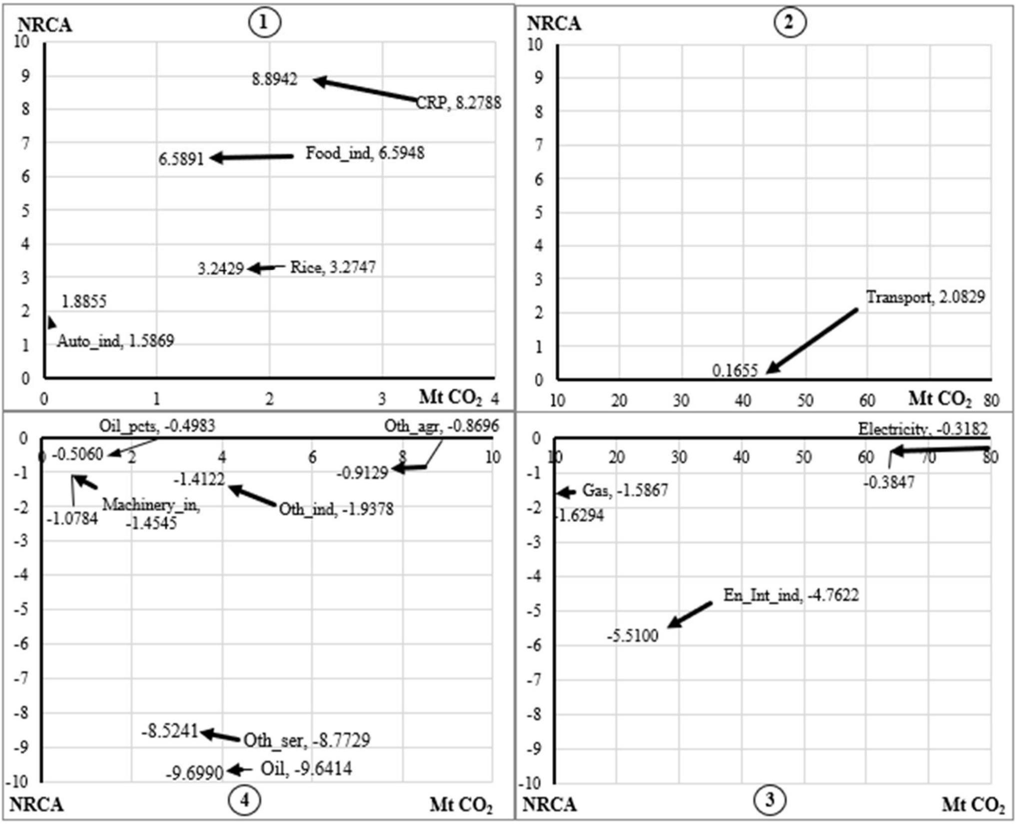
The arrow for Transport sector in the 2nd quadrant is also relatively long (since CO_2 is decreased by 14.82 $MtCO_2$ or 25.4% from its BAU) and also points downward, yet remains slightly positive. This indicates that a 20% CO_2 reduction by the ETS erodes almost all the competitiveness of this highly carbon-intensive service.

The 3rd quadrant of Figure 2 depicts the impact of the ETS for sectors that are highly carbon-intensive and have no comparative advantages. As expected, all arrows point downwards, indicating that their comparative disadvantages are worsening. For instance, Electricity is forced to mitigate 15.93 $MtCO_2$ or 20% from its BAU, the most amount among all sectors.

As mention earlier, sectors in the 4th quadrant are low carbon-intensive but have no comparative advantages. Hence, they are expected to perform worse under the pressure of carbon pricing. Three sectors, Other_agr, Oil, and Oil_pcts, have lower NRCAs as expected. However, NRCAs of these three sectors, namely Oth_ind, Oth_ser, and Machiner_in, are all improved as indicated by the upward trend of their arrows. The results of the improvement in competitiveness of some sectors in the first group and these surprising results of this last group come from the changes in relative prices in the general equilibrium setting, which can be explain as follows.

Carbon pricing changes the relative prices of goods and services in the world economy, increasing the relative prices of high carbon-intensive sectors and decreasing the relative prices of less carbon intensive sectors. Since comparative advantages are determined by the international relative prices, not the absolute prices, some goods, which are initially cheaper, end up being relatively cheaper than before. They will gain even more comparative advantages, as it is the case for CRP and Auto_ind sectors in the 1st group. Some goods that are initially slightly expensive, and so they initially have no comparative advantages, now become relatively less expensive because they do not impose as much the carbon price as those high carbon-intensive sectors. Thus, the comparative disadvantages decreases, as happened in the case of Oth_ind, Oth_ser, and Machiner_in sectors in the 4th group.

Figure 2. Impact of unilateral ETS on Thailand's competitiveness and CO_2 emission by sectors



Sources: Same as Figure 1 and from the simulation under TETS.

Comparing the impact of ETSs and Carbon Taxes on Thailand's Competitiveness

The general conclusion from Figure 2 is that Thailand unilateral ETS causes all sectors to emit less CO_2 at the rate that is positively correlated to their carbon intensity. The unilateral ETS impacts on their competitiveness, however, can be either decrease or increase. An interesting question is which measure among our four scenarios is the most conducive to Thailand's competitiveness?

Table 7 summarizes and compares the percentage changes of Thailand's NRCAs by sectors for all four scenarios. Note that the direction of changes for each sector are consistently the same for all scenarios, although the magnitudes are slightly different. Therefore, Figure 2 should roughly depict the direction and magnitude of carbon pricing impacts on the competitiveness of each sector for all four scenarios. Notice also that there are 12 sectors out of 18 sectors in the table in which the joint carbon pricing measures generate higher NRCAs than their unilateral counterparts (shown by positive signs in the 4th and the last columns of Table 7).

We select one representative sector from each of the four groups in Figure 2 to further compare the impact among these four scenarios. The 1st quadrant of Figure 3 depicts the case of chemical, rubber, and plastic products (CRP), which represents the sector that is low carbon-intensive and competitive, with a positive NRCA index. For this sector, JCTax induces the best outcome for CRP since the joint carbon tax scheme improves the NRCA index the most to 8.90 with the least CO_2 mitigation impact. Both UCTax and UETS generate roughly the same NRCA improvement, but UETS requires more CO_2 mitigation. JETS impacts worst since it is the only one that decreases the NRCA for this sector.

The 2nd quadrant of Figure 3 depicts the case of Transport sector, which represents the high carbon intensive and competitive sector. All carbon measures decrease the competitiveness, but both carbon tax measures cause less burden on both CO_2 mitigation and competitiveness.

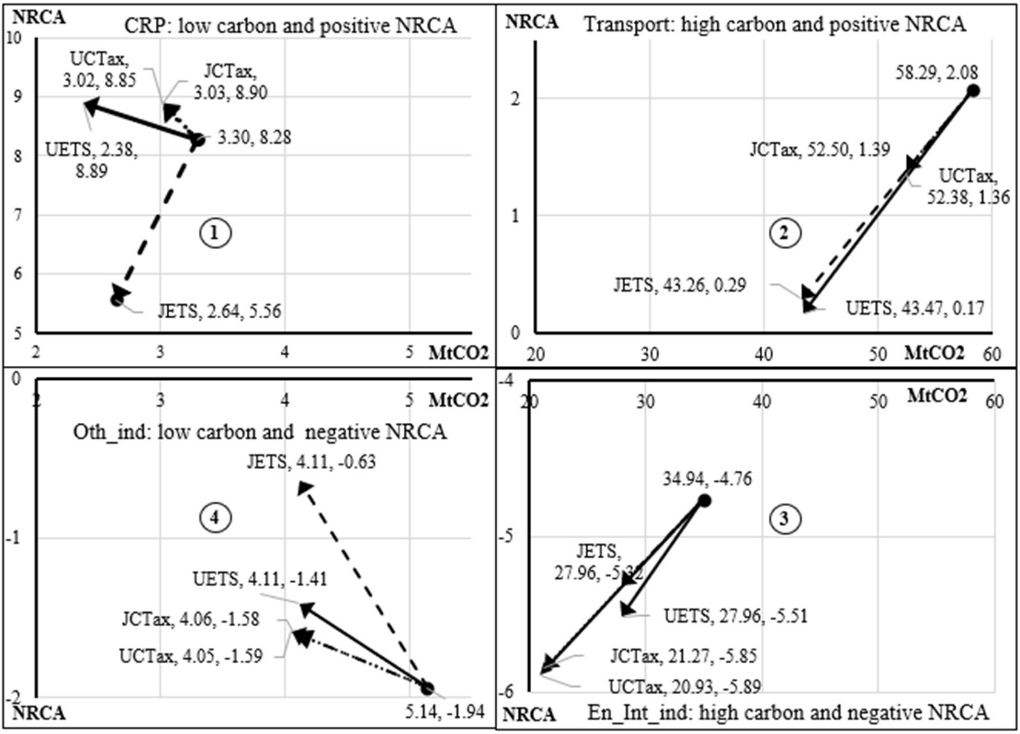
Table 7. Impact of ETSs and Carbon Taxes on Thailand's Competitiveness

Unit: % change from BAU*

Sectors	UETS	JETS	JEST-UEST	UCTax	JCTax	JCTax-UCTax
Electronic_i	5.86%	6.00%	0.14%	5.86%	5.90%	0.04%
CRP	6.91%	7.79%	0.88%	6.89%	7.47%	0.58%
Food_ind	1.11%	1.02%	-0.09%	1.11%	1.02%	-0.09%
Rice	-0.37%	-0.54%	-0.17%	-0.37%	-0.49%	-0.12%
Transport	-34.63%	-33.30%	1.33%	-34.68%	-33.33%	1.35%
Auto_ind	10.71%	8.22%	-2.49%	10.73%	8.12%	-2.61%
Sugar	-0.87%	-0.84%	0.03%	-1.06%	-0.84%	0.22%
Electricity	-16.63%	-16.32%	0.31%	-16.66%	-16.16%	0.50%
OilSeed	-0.93%	-0.90%	0.03%	-0.93%	-0.88%	0.05%
Oil_pcts	-0.84%	-20.25%	-19.41%	-0.35%	-13.83%	-13.48%
Oth_agr	-2.54%	-2.43%	0.11%	-2.55%	-2.37%	0.18%
Coal	-0.41%	0.10%	0.51%	-0.42%	0.09%	0.51%
Machinery_in	12.92%	10.11%	-2.81%	12.98%	10.61%	-2.37%
Gas	-1.11%	-1.23%	-0.12%	-1.10%	-1.47%	-0.37%
Oth_ind	18.12%	18.30%	0.18%	18.12%	18.24%	0.12%
En_Int_ind	-23.63%	-22.91%	0.72%	-23.64%	-22.77%	0.87%
Oth_ser	1.45%	1.57%	0.12%	1.45%	1.57%	0.12%
Oil	-0.69%	-0.46%	0.23%	-0.69%	-0.51%	0.18%

Sources: Calculated from NRAC index given in equation (2) from GTAP-E simulation results.
Note: *To ensure correct signs for the initial negative values, the percentage changes are calculated by (V'- V)/ABS(V), where V = initial value, V' = new value, and ABS() is the absolute value.

Figure 3. Impact of ETSs and Carbon Taxes on Thailand's Competitiveness in selected sectors



We choose energy intensive industries (En_Int_ind) as a representative of the high carbon intensive and not competitive sector. The impacts are shown in quadrant 3 of Figure 3. The impact patterns are similar to those in the 2nd quadrant, except that this time, the ETS measures cause less impacts on the competitiveness.

Finally in the 4th quadrant, other industries sector (Oth_ind) is used as a representative of the low carbon-intensive and not competitive sector. In this example JETS measure helps improve this sector's competitiveness the most. UETS measure is ranked the second while the remaining carbon tax measures perform about the same. Especially those sectors that are highly carbon intensive. Carbon pricing also can, on the other hand, enhance sectors that are not carbon intensive. The second important point is the joint carbon pricing implementation by ASEAN members on average help to alleviate the negative impacts on competitiveness as compared to the unilateral carbon pricing implementation.

5. Concluding remarks and policy implications

The main purpose of this paper is to provide an economic analysis such that policy makers may decide which carbon pricing measures, between carbon market or Emission Trading System (ETS) or carbon taxes, should be more appropriate for Thailand based on their impacts on production, consumption, exports, imports, social welfare and international competitiveness. Using GTAP-E version 9 to simulate the implementation, we were able to obtain and compare important economic variables between different measures. Furthermore, the degree of international competitiveness by sectors, measured by the NRCA index, was analyzed and compared.

Among the four implementations considered, our conclusion is that the carbon tax measure that is jointly implemented by 5 ASEAN countries is the most suitable for Thailand. This is because it can mitigate carbon dioxide emission to the target level while generating less negative impacts on production, consumption, exports, imports, social welfare. It also causes less unfavorable economic effects as compared to the case of Thailand’s unilateral carbon tax implementation or the case of carbon market, either unilaterally or jointly. Both carbon taxes and ETS, for the same mitigation target, does not significantly affect Thailand’s international competitiveness. However, joint carbon tax measure has fewer negative impacts on competitiveness as compared to the unilateral implementation and yet also improves Thailand competitiveness in some sectors.

The above result implies that if, in the future, Thailand has to decide to use a carbon pricing measure to cope with higher mitigation pressure from the UNFCCC, a joint carbon tax among ASEAN countries should be Thailand's first choice. A joint ETS among ASEAN can also be the alternative measure on the negotiation table since this paper has found that the joint carbon pricing are generally more suitable than a unilateral one by an individual country. This unity of ASEAN policy on climate change will also strengthen the spirit of ASEAN community and the negotiation power of the group.

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