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Assessment of Thailand Socio-Economic Impact towards Greenhouse Gas Mitigation Actions in 2030 Using a Computable General Equilibrium Model

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The threat of climate change has urged increased global awareness and apprehension concerning interactions between society, the economy and the environment. Thailand has made a pledge to the United Nations in the form of NDC (National Determined Contributions) committing that the Kingdom will reduce its GHG emissions within 2030 by 20 % through its own efforts and by 25 % with international support on technology transfer and capacity building compared to the emissions in BaU. To support the GHG emissions reduction target, the country has adopted several mitigation plans including its own sustainable development plan, energy efficiency plan, and renewable energy plan, as well as a sustainable transport plan and others. This study aims to elaborate on the country's socio-economic impact as it strives to achieve the NDC mitigation target by 2030 using a variety of sustainability scenarios. The research approach used a recursive dynamic computable general equilibrium model of Thailand. The result of employing the model showed that introducing GHG mitigation actions in industrial energy efficiency improvement could help increase GDP by 1.9 % in 2030 compared to BaU. However, it would also increase the GHG price by 2,517 THB/t CO_2-eq due to the increase of energy usage from enhanced devices and machinery efficiency. Cryogenic carbon capture technology could minimize GDP loss by 0.4 % while drastically reducing GHG price by 3,978 THB/t CO_2-eq compared to a scenario without mitigation action. Combined energy efficiency improvement and cryogenic carbon capture actions show the best result since it potentially increases GDP by 2.1 % compared to BaU while also reducing GHG price by 2,747 THB/t CO_2-eq compared to a scenario without mitigation action in 2030. Primary energy supplies in this study have also been shifted from high carbon content to clean energy in all mitigation action scenarios.

1. Introduction

Climate change is an unavoidable and urgent global challenge with long-term implications for the sustainable development of all countries. Yusuf and Francisco (2009) showed that Thailand is one of the world's most vulnerable countries due to its long coastlines as well as its heavy dependence on agriculture, forestry and natural resources. Millions of people in Thailand are projected to experience water stress by 2050, with the entire capital city of Bangkok projected to experience a high risk of being under water due to the increased sea level. Crops and yield in related agricultural sectors are likewise projected to decline due to the droughts affected by climate change. Taking climate change as a main concern, the Thai government has ratified the Paris Agreement to reduce GHG emissions by 20 % using the country's own effort and by 25 % with international support within 2030 compared to BaU emissions (ONEP, 2015). In order to achieve sustainable development, part of the strategy for the country's 20-year master plan has emphasized low carbon emissions and a climate-resilient society. However, there are a very limited number of studies that elaborate on the impact of future policy in relation to GHG emissions and socio-economic impact, despite it being very important for policymakers and government officials to be notified for appropriate actions. As a result, policymakers cannot properly propose an effective policy. From a global perspective, previous research found that there was an increase of environmental management as well as the increase of ISO 14001 environmental

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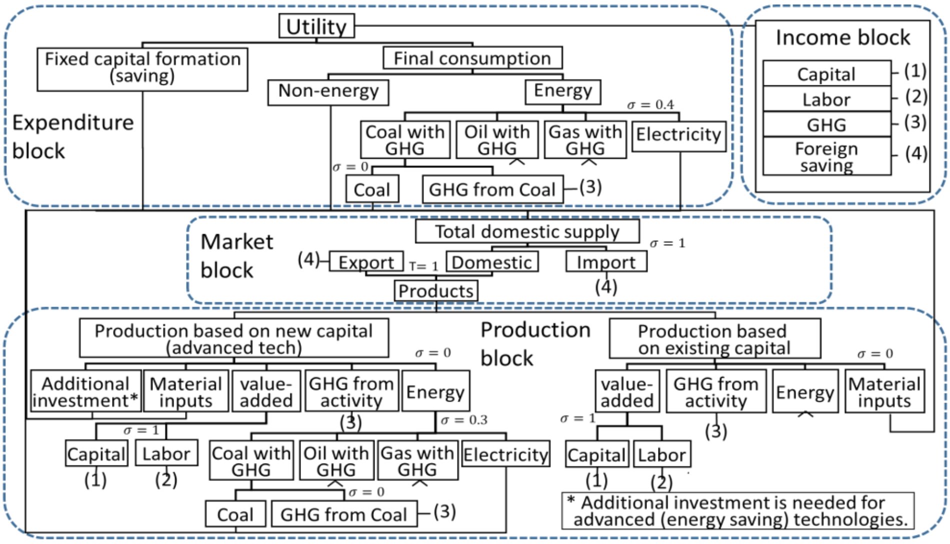
standards being implementing in many production processes (Salim et al., 2019). However, this research did not cover the assessment of future scenarios. In Thailand, previous study results showed the effort of GHG emissions reduction by switching the mode of motorized transportation into non-motorized mode to reduce GHG emissions in specific areas (Hanpattanakit et al., 2018) and by future clean transport scenarios (Sritong and Limmeechokchai, 2014). Similar to previous study, this study did not cover the socio-economic impact assessment of Thailand. In another Asian country, the study of low carbon transformation in India in order to achieve the global 2 °C temperature stabilization target by the energy efficiency shows the good practice of effort as well as progressive environmental policy of India to achieve GHG emissions reduction target (Dhar et al., 2018). Anyhow, this study focuses only on technology selection rather than the macro viewpoint of economic impact. A study by Li and Masui (2018) showed the use of carbon tax implementation in China. The research results showed positive outcomes since carbon tax can reduce GHG emissions in the scenario setting. However, this research did not extend the research to cover mitigation action to reduce carbon tax as an economic burden. Relating to carbon capture technology, a recent study showed the amino-functionalized graphene oxide on its surface as a potential material to capture CO_2 (González-barriuso et al., 2019). Nonetheless, the current study focused only on technology development rather than on its implication related to economic policy. The objective of this study was to assess Thailand's socio-economic impact when introducing GHG emissions mitigation actions in power and industrial sectors aligning with the government's present policies as well as future technologies scenarios. Aside from this section, section 2 provides an explanation of the model structure. Section 3 presents the results and analysis, while section 4 provides the conclusion of this study.

2. Model structure and scenarios

This study applies a country level, multi-sectoral approach with recursive dynamic computable general equilibrium (CGE) model (Limmeechokchai et al., 2019) replicating Thailand's multi-sectors input-output table in 2010 as benchmark data to analyze quantitative economic and environmental impact through the introduction of greenhouse gas mitigation options compared to not introducing greenhouse gas mitigation options.

2.1 CGE model structure

Figure 1 shows CGE model structure. The details of the structure are described in succeeding subsections.



σ : elasticity of substitution, T: elasticity of transformation

Figure 1: The relation between each sector in the CGE model

2.1.1 Production sector

Each production sector consists of 2 activities: activity using existing capital and activity using new capital (investment). Each activity has different technologies: existing technology and advanced technologies. There are several levels of nested production in each production activity. At each level, a virtual firm is assumed to maximize their profit subject to corresponding production technology. At the first top level of the nested production function, it is assumed to use a Leontief production function among energy composite, value added and material inputs. The second nesting parts are value added, which include capital and labor using the Cobb-Douglass production function and the energy composite input into the model using the CES production function. Since the elasticity of substitution number is not the focus, the number of elasticity for substitution has been adopted from another study (Ban and Okagawa, 2008). Lastly, each energy input nest is a composite of energy itself and GHG emission; energy consumption will generate GHG emissions. In this nesting part, the Leontief production function is assumed. Since GHG emission is the study focus, the model is set to have an option that the GHG price will become a positive value to control the emissions if total GHG emission potential exceeds the GHG limit. Even though the GHG price is equivalent to carbon tax, it is not implemented in Thailand. This study treats carbon emissions as a necessary certification; once a company or individual wants to release GHG emissions, the purchase of certification for GHG emissions is necessary.

Compared to production using existing capital, production using new capital also has a similar structure. Still, efficiency of new capital is improved over existing capital. In the next period, the new capital is combined to existing capital in the same sector, while existing capital cannot move to other sectors. The capital efficiency, labor productivity and energy efficiency of the existing capital are updated based on new technologies. New capital should also be possible to install in any sector.

2.1.2 Household sector

Households comprise the final consumption sector. Household representatives receive income from their capital and labor markets. Income in this sense is used for either final consumption or capital investment (household saving). Households maximize utility by choosing levels of consumption for preferred commodities, subject to the constraints of income and commodity price.

2.1.3 International transaction

Like most other countries' CGE models, this model assumes a small open economy, meaning that an economy is small enough so its activities do not affect world price or incomes. The implication is that export and import prices are exogenous. In this study, the relationship between export and domestic supply is defined by CET function and the relationship between import and domestic goods is defined by Armington's assumption.

2.1.4 Dynamic process

As a recursive dynamic CGE model, the model will be solved at one period of a time. Selected parameters including capital stock, labor force, efficiencies and intermediate input-output coefficient are updated based on the modeling of inter-temporal behavior change and results from previous periods. The early step of the dynamic process is to define future GDP growth rate. In each period of iteration, total investment is decided to meet the expected GDP growth rate in advance. The investment is used as new capital in the next period, and the distribution among sectors is decided internally to maximize social utility. The existing capital stock is depreciated, but the additional investment will enhance future capital stock. This study assumes the depreciation rate at 5 % annually. Note that existing capital (equipment) not be moved to other sectors. When new capital is installed, it cannot be moved to any sectors.

2.2 Input Data for CGE model

This study uses the input-output table for Thailand as inflow data for intermediate demand, final demand and value added in the CGE model. The latest update input-output table of Thailand was in 2010, which originally comprised 180 sectors. For simplicity of the model, the 180 original sectors have been aggregated into 22, as shown in Table 1 (classified by energy sectors and non-energy sectors).

Table 1: Input-output table sectors used in this study

Non-energy sectors (17)			Energy sectors (5)
Agriculture	Leather	Paper & pulp	Charcoal
Other petroleum products	Wood	Non-metal	Coal
Mining	Water	Metal & machinery	Gas
Petrochemical	Construction	Transport	Petroleum
Food & Beverage	Wholesale & retail	Other sectors	Electricity
Textile	Services		

2.3 Scenarios design for this study

The target year in this study is 2030, which is the target year set by National Determined Contribution (NDC). The Thai government is committed to UNFCCC in reducing GHG emissions by 20 %. From the previous record of Nationally Appropriate Mitigation Actions (NAMAs), existing GHG emissions reduction in Thailand estimates 4 % reduction with 7 % anticipated by 2020 compared to BaU. Hence, this study needs to continuously assess socio-economic impact related to new NDC target that extended the NAMAs target to 2030 with 20 % GHG reduction target compared to BaU. There are 5 scenarios in this study.

2.3.1 BaU: Reference scenario without limitations on GHG emissions

In BaU scenario, everything is typical. Thai people have no concern for GHG emissions and GHG price has not yet been introduced.

2.3.2 NDC: Limited GHG emission by 20 % compared to BaU without additional mitigation actions

In NDC scenario, 20 % GHG emissions mitigation target is adopted from NDC to implement in the model. GHG price has been introduced to limit GHG emissions to achieve the emissions target with no mitigation introduced to prevent GHG emissions.

2.3.3 M1_CCU: NDC+ introducing CCU technology in power sector

In M1_CCU scenario, Cryogenic Carbon Capture (CCU) technology is introduced to reduce carbon emissions from fossil-fuel power plants on top of NDC. To do this, CCU technology uses phase change to separate CO_2 and other pollutants from exhaust gases (Safdarnejad el al., 2016). It requires additional investment on installing the advance cooling system near the exhaust gas ventilation, together with building up a structure to support the cooling system with power plant. This technology is good because it allows the system to utilize heat from exhaust gas to generate electricity to drive the cooling system. Remaining warm exhaust gas can also be circulated back to heat the feed water to the boiler. As a result, 99 % of CO_2 emissions from the power plant will be captured. In principle, most carbon captured will be utilized for related industries as valuable material input. However, the immaturity of technology and limitations of data availability make quantifying the value of carbon as material input difficult. This study assumed no carbon material input into the model. To implement this technology, it will require additional investment estimated at 30 % of capital cost in the power sector itself.

2.3.4 M2_Efficiency: NDC + introducing efficiency improvement in the industrial sector

In M2_Efficiency scenario, it will implement energy saving labels for all electric devices and machines in industrial sectors on top of NDC. This study estimates 2 % of additional investment in industrial sector capital cost to install such new devices. The result will lead to 5 % energy savings for industrial sectors.

2.3.5 M3_All: NDC + introducing both CCU and efficiency improvement technologies

In M3_All scenario, CCU technology and efficiency improvement technology will be implemented together on top of NDC. This study uses BaU scenario to compare with NDC, M1_CCU, M2_Efficiency and M3_All scenarios to see the impact of GHG emissions constraint and GHG mitigation actions from the perspective of socio-economic impact.

3. Result and discussion

The future socio-economy of Thailand shows that GDP will reach 23.55×10^{12} THB, while GHG emissions will reach 558 Mt CO_2-eq in BaU by 2030. NDC target will restrict GHG related economic activities in Thailand, resulting in reduced GDP by 1.5 % compared to BaU. With this massive loss, the metal and machinery sector will be significantly impacted since it is energy intensive. Using this study, various socio-economic effects of activities using GHG mitigation actions will be discussed in later sub-sections.

3.1 GDP and household consumption

The cost of measuring these scenarios will be defined by GDP loss due to the reduction of output production. From Figure 2, introducing GHG emissions constraint in NDC leads to GDP loss by 1.5 % in 2030 compared to BaU. By introducing GHG mitigation actions, GDP loss will be 0.4 % lower under M1_CCU scenario as compared to NDC scenario. In M2_Efficiency and M3_All scenarios, the result shows an increase of GDP compared to BaU. The same trend can be found in household consumption loss. Without mitigation action, household consumption loss will be 2.4 % in 2030 compared to BaU. By introducing mitigation actions, household consumption will increase by 0.9 % and 0.4 % in M2_Efficiency and M3_All scenarios compared to

BaU. Apparently, limiting GHG emissions in the CGE model, the production sectors consuming significant energy and generating significant GHG emissions will reduce production. This is due to GHG price, which increases the cost of high GHG production activities made uncompetitive price of products to consumers, so they reduce demand. By introducing mitigation action, the cost of consumption for production activity becomes cheaper. Thus, the model increases production activities, which helps compensate for GDP and consumption loss.

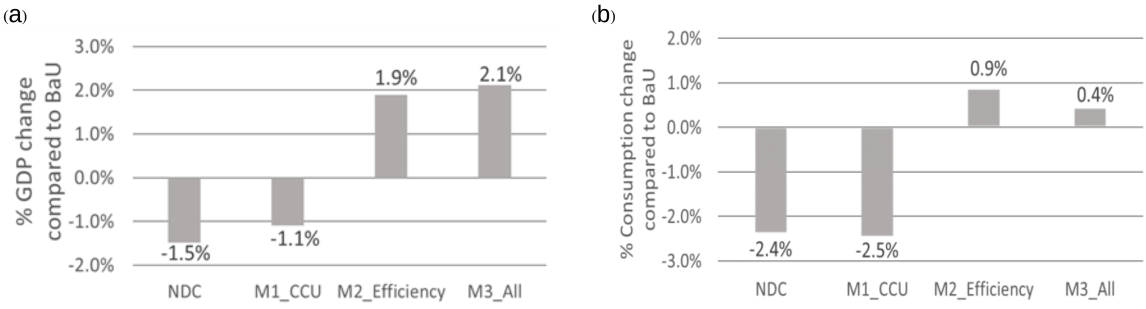


Figure 2: (a) Percentage of GDP change compared to BaU in 2030 and (b) Percentage of household consumption change compared to BaU in 2030

3.2 GHG emissions and GHG price

GHG emissions are significant because it shows the reduction potential of GHG emissions mitigation actions. In this paper, GHG emissions have been combined as one number including CO_2, CH_4 and N_2O. From the CGE simulation, the result shows that GHG emissions in BaU in 2030 will reach 558 Mt CO_2-eq. According to government estimation, Thailand's GHG emissions in 2030 will reach 555 Mt CO2-eq. Compared to the present forecast by government, the model result is higher by 3 Mt CO_2-eq. Limiting GHG emissions by 20 % in 2030 will lower GHG to 448 Mt CO_2-eq. To reduce total GHG emissions by 20 % from BaU level, Figure 3 shows that GHG price in NDC will increase to 6,193 THB/t CO_2-eq in 2030.

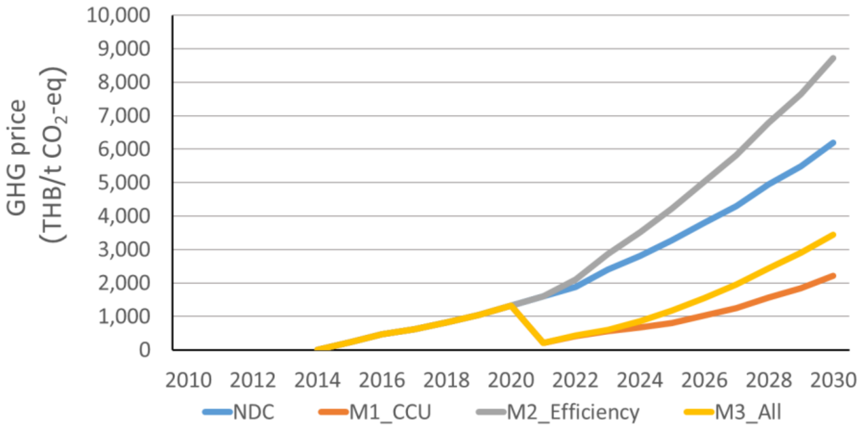


Figure 3 :GHG price during 2010-2030

GHG price will decrease significantly to 2,215 THB/t CO_2-eq in 2030 in M1_CCU. This is due to CCU technology reduces GHG emissions potential, leading to decreasing GHG price. Note that the GHG price result is increased under M2_Efficiency scenario compared to NDC in 2030. That is, rebound effect can be found in this scenario (Alcott, 2005).

This result corresponds with the increase of household consumption in M2_Efficiency as well, which leads to increased GHG emissions with higher GHG price used to control GHG. Introducing CCU technology together with energy efficiency improvement mitigation actions can reduce GHG price by 2,747 THB/t CO_2-eq compared to NDC.

3.3 Total energy supply

Total energy supply will increase in each scenario in accordance with economic growth. In M1_CCU, the cost of introducing new technology is relatively low compared to not introducing CCU technology, so the cost of using energy is low. As a result, it increases the use of total energy by 6.8 % compared to NDC. In M2_Efficiency, rebound effect still makes total energy supply increase by 0.32 % compared to NDC, even after energy efficiency has been introduced. In M3_All, introducing energy efficient technology together with rebound effect enhances the increase of total energy supply by 7.5 % compared to NDC.

4. Conclusion

This study uses GHG price as the main mechanism to control GHG emissions, which inevitably impacts the household sector for the increased price of goods and services. Still, the government can benefit from GHG price since it can be used to compensate household and production sectors to invest in high technology for GHG reduction. By introducing CCU technology and energy efficiency improvement mitigation actions together, the best outcome is possible since it increases national GDP by 2.1 % compared to BaU in 2030 as well as reduces GHG price in 2030 by 2,747 THB/t CO_2-eq compared to NDC. This study also showed co-benefit since renewable energy technology is developing, especially energy storage, which requires more time to mature before commercialization. Thailand is a net-import energy country in which petroleum and coal are mainly imported. However, natural gas is produced in the country. Thus, changing total energy supply from coal and petroleum to gas will help strengthen energy stability in Thailand as well as strengthen the entire economy.

Acknowledgments

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