Incidents of the New Policies for Promoting Trade with Climate Change Consideration:

A Case of Thailand

by

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Chapter 1: Introduction

1.1 Statement of the Problems

With rising environmental awareness, sustainable development has been a central interest in the global community over the past two decades. As defined in the Brundtland Report (1987), sustainable development is "… development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commission, 1987, p. 43). This refers to the relationships among social, environmental, and economic factors. Sustainable development, different from the old paradigm of economic growth, involves more than growth, as it promotes economic growth that benefits the poor and preserves the environment.

Over the past 20 years, many countries have committed to sustainable development goals by introducing economic and social development plans under the concept of sustainability (Drexhage & Murphy, 2010). It has been announced that sustainable development goals (SDGs) will be the core of the UN development agenda at the 2015 Sustainable Development Summit. The reason the UN is shifting development goals toward sustainable development is climate change concerns. Climate change is a worrisome problem from the perspective of economic and social development because it increases the likelihood of environmental degradation, which has adverse effects on the poor, whose sources of income are usually linked with natural resources and ecosystems.

For Thailand, the importance of sustainable development led to the 9th National Economic and Social Development plan (2002-2006), linking sustainable development with a sufficiency economy, which is the principal concept of the ninth plan. In the 10th National Economic and Social Development plan (2007-2011), a people-centered approach to sustainable development was introduced as a tool to reach the main target, a happy society. Sustainable development was highlighted as the fundamental development goal in the 11th National Economic and Social Development plan (2012-2016). Under this plan, the need for the country to shift to a green economy and society is addressed. A central message of green economy is to encourage green production and consumption of low carbon products. Under this development plan, reduction of greenhouse gas emissions is one of the main targets.

Considering Thailand’s development policies in the past, the policy was made to boost economic growth, which is the most important target for economic development at the moment. Numerous policies were imposed to raise national income and enlarge an economy. Alleviating poverty and improving income distribution were also set as development goals. During this period, trade policy was promoted as a leading strategy to boost economic growth. Trade policy was expected to add benefits to poverty alleviation and income distribution as well. Thailand's international trade policy is on track to free trade, as policies of the past 30 years have emphasized export and trade agreements.

Benefits of trade on growth, poverty, and income distribution have been theoretically recognized. Trade enlarges the scope of the market from only domestic to the rest of the world and enhances the efficiency of domestic production by considering comparative advantages. On the other hand, the adverse environmental impacts of trade must be concerned, including resource depletion, pollution, and greenhouse gas emissions associated with climate change. Since the former development goal of Thailand was to foster economic growth, trade promotion took place without environmental concerns. There is evidence that an expansion of the economy under trade promotion could cause environmental problems and rapidly increase greenhouse gas emissions.

An impressive GDP growth rate in the past three decades proves that international trade promotion is an effective measure for stimulating economic growth in Thailand. Incidence of poverty also shows a decreasing trend. This statistical evidence indicates that international trade policy based on the "free trade" pathway is beneficial for Thailand and should be pursued. However, if Thailand desires to move toward sustainable development goals in which a green economy is underlined, trade promotion needs to be revised with climate change take into consideration. Trade that enormously increases greenhouse gas emissions is undesirable.

Building a trade policy to achieve Thailand’s sustainable development goal is the greatest challenge. The desired trade policy requires a compromise between climate change considerations and economic growth. A single trade policy may not adequate to achieve sustainable development goals that address multiple targets. It may be necessary to implement a set of various policies.

In the light of these concerns, this study tries to find the “right” trade policy with climate change considerations. The preferred trade policy is the one that boosts economic growth while minimizing greenhouse gas emissions. Further, poverty and inequality should not get worse after policy implementation. As previously mentioned, trade policy based on a "free trade" concept has proven fruitful for the Thai economy and should be developed. Trade reform, defined as tariff removal, is selected as a representative of free trade policy. To examine whether or not trade reform is the “right” policy, the impacts of trade reform in multi-dimensions, including greenhouse gas emissions, poverty, and income distribution, will be assessed. The assessment aims to acquire accurate results regarding the actual benefits of trade reform on the Thai economy when climate change is taken into consideration. Understanding the impacts of trade reform allows us to propose appropriate policy with reference to climate change and social concerns.

1.2 Objectives of the Study

The research questions were designed as follows.

Main Research Question

Does trade reform really benefit Thailand when climate change and poverty are considered?

Related Questions

i. What are the impacts of trade reform on the economy, greenhouse gas emissions, poverty, and income distribution in Thailand?

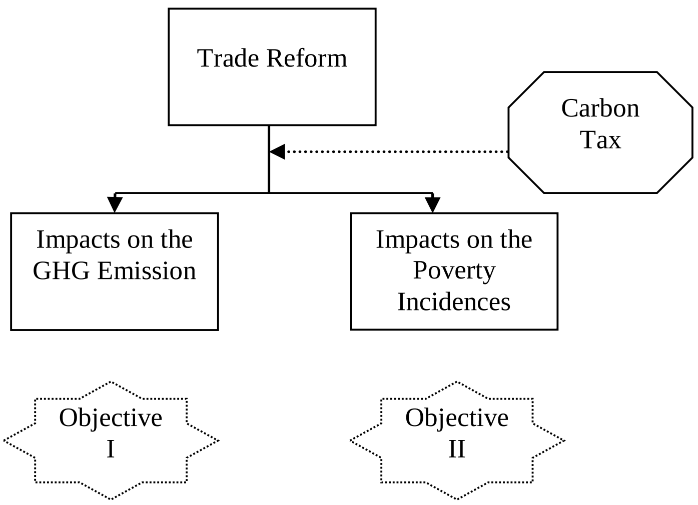
ii. Under trade reform, is carbon tax a necessary measure to control climate change by controlling greenhouse gas emissions? If it is necessary, to what extent should the carbon tax be applied?

Based on the research questions, there are two objectives of the study. The first objective is to analyze the impacts of trade reform on greenhouse gas emissions in Thailand with respect to the role of carbon tax. The second objective is to assess the impacts of trade reform and carbon tax on poverty and income distribution in Thailand.

1.3 Research Framework

Following the research objectives, the research framework is established as below.

Figure 1-1: Research Framework



Source: Author's compilation

For the first objective, the impacts of trade reform on greenhouse gas emissions are assessed with and without a carbon tax implemented. For the second objective, the impacts of trade reform are assessed in the same way, but its impacts on poverty and income distribution are considered. The basic research framework is illustrated in Figure 1-1. Details of the research framework and methodology will be described in Chapter 3.

1.4 Scope of the Study

This study estimates impacts of trade reform on greenhouse gas emission, poverty, and income distribution with and without carbon tax implemented. Trade reform is described in two manners: full trade reform and partial trade reform. Full trade reform is an import tariff reduction across all sectors. Partial trade reform is an import tariff reduction in carbon- intensive sectors. Environmental impact is defined as levels of greenhouse gas emissions. Other indicators of environmental degradation, such as air pollution, soil degradation, and water pollution, are not considered in this study due to data availability. An analysis is done at a national level and global impacts are not considered. A main methodology used in this study is the static computable general equilibrium model, thus impacts of trade reform and carbon tax are assessed in a single period, the year 2007.

1.5 The Organization of the Study

There are six chapters in this study. Chapter 1 describes an introduction of the study comprising a statement of the problems, the objectives of the study, the research framework, the organization of the study, the scope of the study, and the contributions of the study. Chapter 2 provides information on international trade, poverty and income distribution, and the climate change situation in Thailand. Chapter 3 provides a detailed explanation relating to model specifications and methodology. Chapter 4, the first analytical chapter, discusses the impacts of trade reform on greenhouse gas emissions in Thailand, with and without the implementation of a carbon tax. The analysis of this chapter matches with the first research question discussed above. Chapter 5, following the secondary research questions, assesses the impacts of trade reform on poverty and income distribution in Thailand, with and without a carbon tax. Chapter 6 presents conclusions, policy recommendations, and suggestions for future study.

1.6 The Contributions of the Study

An analysis of trade reform with regard to climate change considerations is fruitful in four ways. Firstly, it verifies the relationship between international trade and greenhouse gas emissions that remains unclear. Secondly, it provides an understanding of the benefits of Thailand trade reform considering economic, social, and climate change factors. This knowledge is important for Thailand in terms of policy implications. It shows the effectiveness of trade reform policy to achieve the goal of sustainable development. Thirdly, this study investigates the impacts of trade reform with the most up-to-date data. The latest study on this issue employs data from 1998, which seems to be out of date and may not give accurate results. Lastly, this study explicitly proposes a combined trade reform and carbon tax policy to create a "new" policy that Thailand can use to accomplish sustainable development, while previous works have addressed only a single policy.

Chapter 2: Discussions on International Trade, Climate Change, and Poverty in Thailand

This chapter gives an overview of Thailand's economy, mainly including the topics of international trade, climate change, and poverty that are the central interests in this study. A conversation on this topic is worthwhile, as it provides the knowledge needed for the discussions of the analytical results and policy implications in the following chapters.

The chapter is organized as follows. An overview of the Thai economy is presented in Section 2.1. Section 2.2 briefly reviews the historical background of international trade in Thailand. Thailand trade policy reform is discussed in Section 2.3. Some key environment and climate change issues are presented in Section 2.4. Section 2.5 describes poverty and income distribution in Thailand.

2.1 Thailand Macroeconomic Indicators: An Overview

Before the Asian economic crisis in 1997, Thailand had an impressive record of economic growth. Thailand was one of the fastest growing economies in Southeast Asia. From the 1960s to the 1980s, the gross domestic product (GDP) increased at an annual rate of 7%, on average.

Table 2-1 provides some important data regarding economic indicators for Thailand from 1996 to 2013. After recession from economic crisis in 1997, Thailand returns to strong GDP growth since 2000. In 2011, the World Bank upgraded Thailand's income categorization from a lower-middle income economy to an upper-middle income economy. Thailand's GNP per capita was about US$ 5,943 in 2013.

The growth of the GDP has corresponded with an increase in the percentage of economic activity accounted for by international trade. The volume of exports and imports has risen steadily. Export volume increased from US$ 54.7 billion in 1996 to US$ 225.4 billion in 2013. At the same time, import volume increased from US$ 63.7 billion in 1996 to US$ 218.7 billion in 2013. Apart from the benefits to economic growth, a surplus trade balance is one of the sources of international reserves in Thailand. It is essential to note that changing from a fixed exchange rate to a floating exchange rate system after an economic crisis is one factor that determined the impressive growth in exports.

Table 2-1: Thailand's Key Economic Indicators

	1996	1998	2000	2002	2004	2006	2008	2010	2012	2013
1. Population										
(Million Persons)	59.90	61.20	61.88	62.80	61.97	62.83	63.39	63.88	64.46	64.79
2. GDP at Current Price										
(Billions of Baht)	4,638.6	4,701.6	5,069.8	5,769.6	6,954.3	8,400.7	9,706.9	10,802.4	12,354.7	12,910.0
GDP (% Change)	10.0	-0.2	5.8	7.9	10.1	10.3	6.9	11.9	9.3	4.5
3. GNP per Capita										
(Baht: Person)	75,875	74,202	79,853	88,420	104,452	125,551	144,147	156,643	178,199	182,617
4. Consumer Price Index										
(2011=100)	76.40	85.70	87.90	89.40	89.90	93.40	96.60	97.69	102.10	103.12
5. External Account										
5.1 Export (BOP Basis)										
(Billions of US$)	54.7	52.9	67.9	66.1	94.9	127.9	175.2	191.6	225.7	225.4
(% Change)	-1.9	-6.8	19.5	4.8	21.6	17.0	15.9	27.1	3.0	-0.1
5.2 Import (BOP Basis)										
(Billions of US$)	63.7	36.6	56.2	57.0	84.2	114.3	157.9	161.9	219.1	218.7
(% Change)	0.6	-33.8	31.3	4.6	10.7	7.8	26.7	37.0	8.4	-0.1
5.3 Trade Balance										
(Billions of US$)	-9.0	16.3	11.7	9.1	10.7	13.7	17.3	29.8	6.7	6.7
5.4 Current Account Balance										
(Billions of US$)	-14.3	14.3	9.3	4.7	2.8	2.3	2.2	10.0	-1.5	-3.9
5.5 Net Capital Movement										
(Billions of US$)	19.5	-9.8	-10.3	-1.8	3.6	8.1	12.6	24.8	12.8	-4.2
5.6 Balance of Payments										
(Billions of US$)	2.2	1.7	-1.6	4.2	5.7	12.7	24.7	31.3	5.3	-5.0
5.7 International Reserves										
(Billions of US$)	38.7	29.5	32.7	38.9	49.8	67.0	111.0	172.1	181.6	167.2
5.8 Total Debt Outstanding										
(Billions of US$)	108.7	105.1	79.7	59.5	58.8	70.0	76.1	100.6	130.7	141.9
6. Government Finance										
(Fiscal Year)										
6.1 Overall Cash Balances										
(Billions of Baht)	104.3	-115.3	-116.6	-118.7	17.2	4.5	-24.0	-200.4	-287.0	-208.9
6.2 Total Public Debt										
(Billions of Baht)	548.7	2,073.5	2,804.3	2,943.0	3,126.6	3,233.1	3,408.2	4,230.7	4,937.2	5,430.6
Domestic Debt										
(Billions of Baht)	288.6	1,598.3	1,937.9	2,118.8	2,455.9	2,727.0	3,020.8	3,868.2	4,596.6	5,052.5
7. Exchange Rate										
(Baht: US$)	25.34	41.37	40.16	43.00	40.27	37.93	33.36	31.73	31.08	30.73

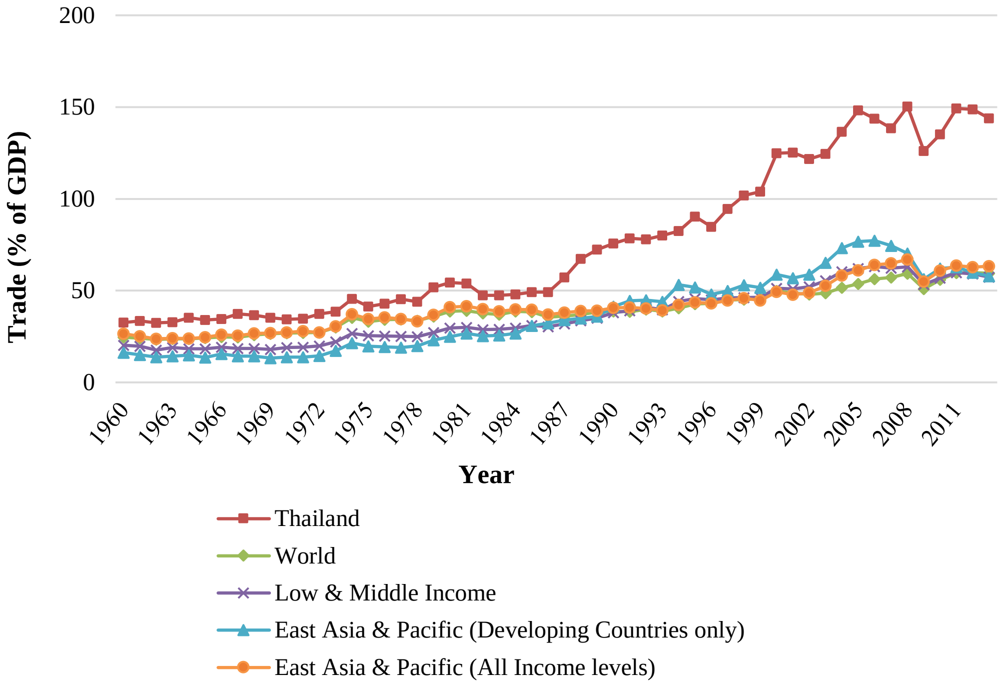
Source: Bank of Thailand (Data extracted on 15 July 2015)

The above discussion of the characteristics of Thailand’s economy shows that one of the most important contributors to economic growth has been international trade. Therefore, reductions in trade barriers, defined as trade reform in this study, should be beneficial for the Thai economy. To provide a clear picture of the relationship between international trade and economic growth in Thailand, international trade statistics and Thailand’s trade policy are discussed in the next section.

2.2 Background of International Trade in Thailand

For Thailand, trade has been the primary source of economic growth over the past three decades. As presented in Figure 2-1, the degree of openness, the ratio of the country's total international trade (the volume of exports and imports) to the gross domestic product, shows that international trade has played an important role for the Thai economy. The degree of openness index of Thailand is high compared with indexes for other low- and middle-income countries, East Asia and Pacific countries, and the world. This implies that the Thai economy has a strong link with the global economy. Based on the importance of international trade on the economy, a trade policy or macro policy that affects the country's total international trade should be applied carefully.

Figure 2-1: The Degree of Openness



Source: World Development Indicators (Data extracted on 15 July 2015)

Promoting international trade as a strategic policy to boost economic growth has a long history in Thailand. During the second national development plan (1967-1971), the Thai government endorsed an import-substitution industrialization (ISI) policy for economic development. The ISI was an international trade and economic policy that supported domestic production rather than foreign imports. Heavy protection, including high tariff walls, import quotas, and import restrictions, were imposed. A primary objective of the ISI was to encourage expansion and competition in domestic industries. It enhanced forward and backward linkages in industrial processes and economies of scale. With the ISI policy, local Thai manufacturing concentrated on serving the domestic market, not on the export market. The ISI policy brought about the growth of the manufacturing sector that contributed substantially to GDP of Thailand.

The success of the ISI policy required a large and efficient local demand to absorb domestic production. However, the small domestic market and an increase in trade deficits in the 1970s put pressure on the ISI policy as a key government policy. To maintain economic growth, the policymakers pursued an export promotion policy. The ISI policy was terminated in the fourth national economic development plan (1977-1981) and was replaced by export promotion, which was publicly enforced as the main strategy for boosting economic growth. In the early 1980s, Thailand confronted an economic crisis similar to the ones that hit other developing countries, and had to enforce the Structural Adjustment Loans programs (SALs) of the World Bank and the Stand-by Arrangements of the International Monetary Fund (IMF). Under the support and advice from the World Bank and the IMF, the export promotion policy was emphasized because it was expected to increase exports and to reduce the balance of the country's debts.

Under an export-led growth strategy, the Thai government implemented several measures, such as tax rebates, tariff reductions, preferential interest rates on short-term loans, and established a duty-free export-processing zone. An export-oriented policy was believed to boost economic growth, raise national income levels, upgrade labor productivity, reduce poverty, and equalize income distribution.

Export promotion appeared to be effective in promoting manufactured exports and GDP growth. The GDP increased remarkably. The economic growth accelerated from 3.5% in

1985 to 9.5% in 1987 and 13.2% in 1988. Roughly speaking, Thailand succeeded in using the export promotion policy to foster economic development in the short- and medium-term. This led to a belief in Thai policymakers that Thailand was going to be a Newly Industrialized Country or NIC.

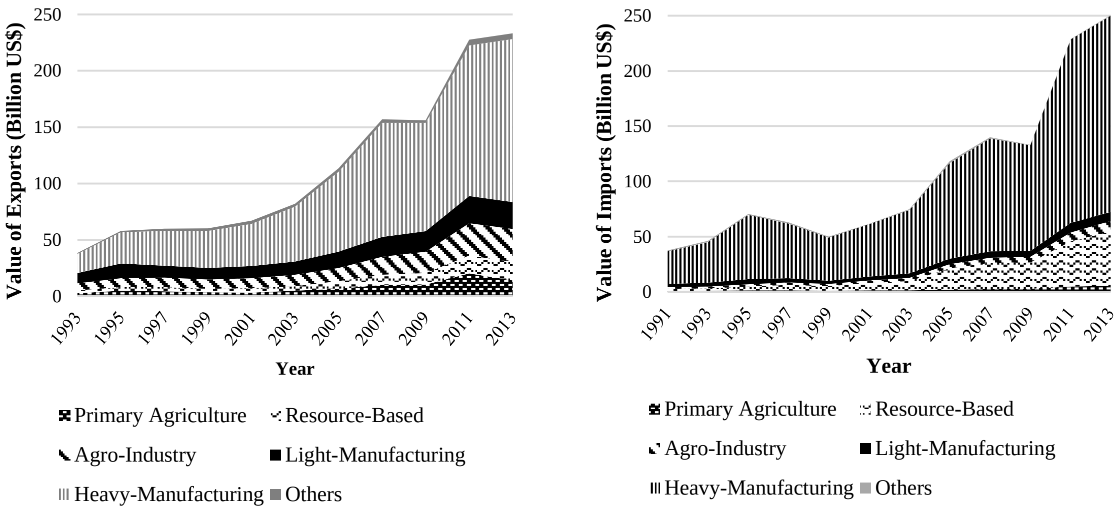
Apart from the export promotion strategy, Thailand entered into several multilateral and bilateral trade liberalization agreements. In 1981, Thailand signed the General Agreement on Tariffs and Trade (GATT) (Tokyo round negotiations), which can be roughly regarded as the first pace of trade liberalization. Recently, Thailand joined several multilateral trade agreements (the World Trade Organization (WTO), the ASEAN Free Trade Area (AFTA), and Asia-Pacific Economic Cooperation (APEC)) and bilateral trade agreements such as Free Trade Agreements (FTAs) with Australia, New Zealand, India, Japan, and Peru. Those multilateral and bilateral agreements resulted in a reduction in tariffs and non-tariff barriers to trade.

In summary, during the period of export promotion policy and trade liberalization under multilateral and bilateral trade agreements, the importance of international trade on the Thai economy has continued to increase. The value of foreign trade has steadily risen, especially since the economic crisis in 1997 when the Thai economy depended heavily on exports.

During the ISI policy phase and the first phase of export promotion policy, Thai exports relied heavily on primary agricultural and natural resource-based products. However, the structure of exports changed when trade liberalization was applied. The export of manufactured goods became more and more important, particularly exports from the light manufacturing and agro-industries, while the relative importance of primary agriculture exports declined. The composition of exports from 1991-2013 is illustrated in Figure 2 2 (a). During this period, Thailand's exports shifted towards the heavy manufacturing sector. Heavy manufacturing is a key export sector, followed by the agro-industry and light manufacturing sectors. Particularly, major export goods were vehicles, automatic data processing, refined fuels, jewelry, and Polyethylene (Ministry of Commerce, 2013). Export composition and the major export products reveal the importance of heavy manufacturing industries in Thai exports.

For the imports, Figure 2-2(b) presents the import structure of Thailand. Thailand's major import sector is the heavy manufacturing sector. The main import products in this sector are machinery, electrical machinery, chemical products, and iron and steel. The imports in the resource-based sector increased continuously as a result of the expansion in imports of crude oil as an input of petroleum refineries.

Figure 2-2 Thailand Export and Import Structures



(a) Composition of Thai Exports

(b) Composition of Thai Imports

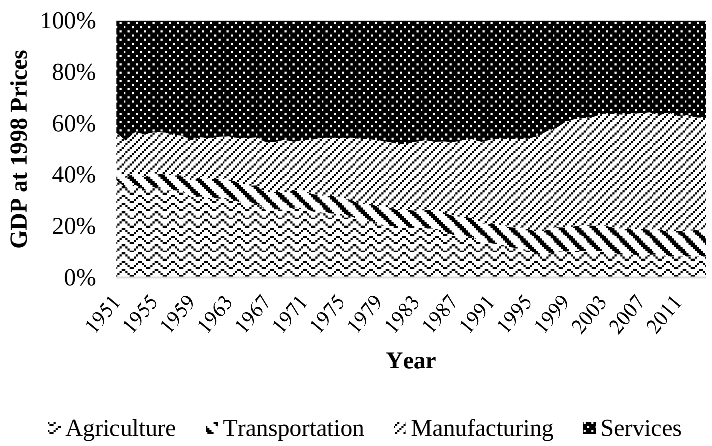
Source: Ministry of Commerce, Thailand (Data extracted on 15 July 2015)

With changes in the trade structure, the economic structure of Thailand has changed accordingly. Figure 2-3 illustrates the structural changes in the Thai economy from 1951 to 2014. The economic structure was represented by the GDP, classified by activities such as agriculture, transportation, manufacturing or industry, and services. The figure shows that the Thai economy depended on the agricultural sector during the 1950s. In the 1960s, the manufacturing share of the GDP started growing. The manufacturing sector turned out to be important, while the agricultural sector was surpassed. The agricultural activity share of the GDP has been declining steadily. It dropped from 37.88% in 1951 to 20.20% in 1980 and only

8.32% in 2014. In the 1990s and later, the industrial sector was the leading contributor to the Thai economy, followed by service sector.

In summary, it can be observed that the manufacturing sector has surpassed the agricultural sector both in production and in exports. It is important to note that the development of manufacturing sectors enlarged the transportation sector as well. The expansion of the transportation sector and manufacturing activity, especially heavy manufacturing production, highlighted questions regarding environmental impacts. It has become somewhat evident that manufacturing, particularly capital-intensive industry and manufacturing using heavy engines, has caused environmental problems in several ways, such as resource depletion, pollution, and greenhouse gas emissions. Environmental issues are addressed in the next section.

Figure 2-3: Thailand Economic Structure



Source: The National Statistical Office of Thailand (Data extracted on 1 September 2015)

2.3 Trade Reform in Thailand

Together with a new export promotion policy, the Thai government launched a trade policy reform in the mid-1980s. Trade reform[1] is an important concern of policymakers because

[1] The phrase "trade reform" is widely used in many previous studies on Thailand's trade policy (see J. Dean, Desai, & Riedel, 1994; Warr, 2009; Wattanakul, n.d.). It usually refers to zero import tariffs. Trade liberalization is also applied with the same meaning.

it is expected to resolve balance of payment problems. Several measures promoting intensive trade and economic integration were applied under the new policy. Among trade barriers, import tariffs are the main barrier of international trade of Thailand. It can be inferred that this is why tariff reduction was the main strategy of trade reform in Thailand.

A major tariff reduction program was implemented in 1982, but it was unsuccessful and had to be withdrawn because of a serious fiscal imbalance due to revenue loss. To recover the fiscal imbalance, tariff rates were raised by 5 percent on raw materials and by 10 percent on final goods. The fiscal balance recovered in 1988, and the Thai government resumed tariff reform. By 1991, tariffs had been significantly reduced, especially for the import of vehicles and computers. Hence, in order to support an export promotion policy, measures such as the remission of tariffs and business taxes on inputs used in exports, the launching of export processing zones, and concessional export credits were also promoted (J. Dean, Desai, & Riedel, 1994).

From the late 1980s through the 2000s, this export promotion policy remained dominant. Thailand also participated actively in trade integration forums. The country joined several multilateral and bilateral trade liberalization agreements, especially after joining the WTO in 1995, and from then on Thailand's tariffs successively continuously decline. The Thai government enforced several obligations of the WTO, in order to eliminate market access barriers. Under WTO commitments, Thailand strengthened its trade policy reforms to promote trade and economic cooperation, especially as they related to the elimination of tariff and non-tariff barriers. For example, quantitative restrictions on several agricultural products have been replaced by tariff measures, and tariff rates on many import agricultural products have decreased. The tariff system in manufacturing sectors has been restructured. The Thai government has also restructured customs tariffs on nine product categories covering a total of 2,990 items, or 39.52% of all customs tariff items (Kohpaiboon, 2008; Thanaphonphan, 2008; Wattanakul, n.d.).

As a result of the economic crisis of 1997, the Thai government has put great emphasis on trade policy. Joining many regional and bilateral free trade agreements (FTAs) was a significant element of Thailand's trade policy and efforts to expand markets and increase its number of trading partners. Since free trade is the key objective of FTAs, it usually induces trade among member countries by promoting zero import tariffs; these, in turn, often result in tariff reductions for several products in member countries. For instance, the tariff reduction programs of the AFTA that were completed in 2003 led to tariff reductions for all ASEAN members.

In conclusion, Thailand's trade policy continues to aim at maintaining an open trade regime (Thanaphonphan, 2008). Tariff reform, particularly tariff reductions, is regularly used as a primary measure of Thailand's trade policy. Tariff reduction leads to changes in import and export structures, government revenue, domestic production structures, and so on. Accordingly, any modifications of tariff rates are important and cannot be overlooked.

2.4 Environmental Problems and Climate Change in Thailand

As discussed in the previous section, international trade and changes to economic structure may have caused environmental problems for Thailand in various ways. To begin with, the link between trade and pollution is discussed.

Trade increases heavy manufacturing, including pollution-intensive industries such as iron and steel, industrial chemicals, pulp and paper, and rubber products.[2] An increase in production in those industries increases pollution to air, water, and soil. Pollution from trade expansion can be dangerous. The Mab Ta Phut site is a powerful example. Mab Ta Phut was established as an export promotion zone of the Board of Investment (BOI) in 1988 in Eastern

[2] Iron and steel, industrial chemicals, and rubber products are major export products of Thailand (Ministry of Commerce, 2013). According to Mani & Wheeler (1998), these three industries are defined as polluting industries.

Thailand. It is the production base of capital-intensive industries such as chemical, metal, oil refining, and other related industries. Industrial development in Mab Ta Phut has caused environmental problems for a long time; for example, in 1996, illegally stored oil drums exploded, killing 17 people and contaminating ground water; in 1997, 40 school children were admitted to a hospital due to nausea, vomiting, and chest pains caused by sulfur dioxide from two chemical plants nearby, which were later investigated by the Ministry of Science, Technology, and Environment that 80% of the students and teachers at that school had suffered from nausea, while 30% had small growths and inflammation in the nasal cavity. In 2000, about 200 residents of Mab Ta Phut were hospitalized after a carbonyl chloride gas leak from the nearby Thai Polycarbonate Company plant. In 2009, serious air pollution in Mab Ta Phut came to the light when the Supreme Administrative Court announced that Mab Ta Phut had become a pollution control zone and the 76 petrochemical and industrial projects in that area were halted. These problems imply that environmental problems due to the expansion of heavy industry seem to be severe.

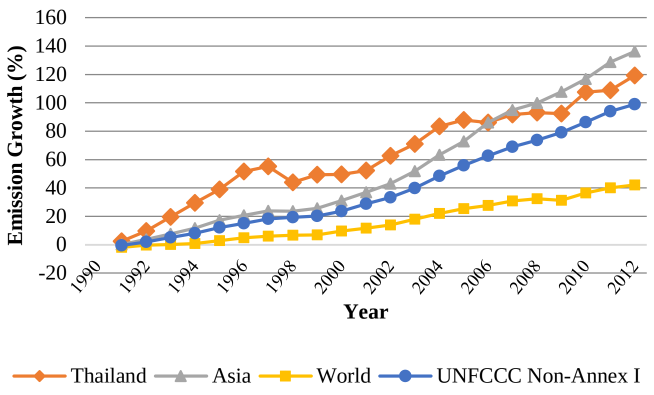
Along with adverse impacts from increased pollution, international trade could contribute to increasing greenhouse gas emissions. Although greenhouse gas does not directly destroy human health and the environment, it contributes to climate change, including global warming, which is currently a central interest of the global community.

The adverse impacts of climate change have been widely noticed, for example, increased or decreased rainfall, reduced agricultural crop yields, and had negative effects on the environment and human health. Scientific evidence shows that the climate change problem derives from greenhouse gasses (GHGs). The Kyoto Protocol[3] has identified six target GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs),

[3] The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change, which commits its Parties by setting internationally binding emission reduction targets.

perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).[4] GHGs are mainly produced from human activities; CO_2 is produced from fossil fuel combustion in transportation, electricity generation, manufacturing, and deforestation; and CH_4 is produced from activities related to agriculture, where N_2O is also produced from using fertilizer.

Figure 2-4: GHG Emission Growth of Thailand and Other Regions



Source: Climate Analysis Indicators Tool (CAIT), World Resources Institute (Data are derived on 15 July 2015)

The climate change problem cannot be ignored in Thailand. In the company of rapid economic growth and structural changes, the volume of GHG emissions continuously increases every year. Figure 2-4 presents the GHG emissions growth in Thailand from 1991 to 2012 compared to emissions growth in Asia, the world, and countries in the United Nations Framework Convention on Climate Change (UNFCCC) Non-Annex I.[5] Thailand signed the UNFCCC in 1992 and ratified the Convention in 1995 as a Non-Annex I country. The figure shows that GHG emissions in Thailand have increased rapidly compared with the world and Non-Annex I countries. The GHG emissions of Thailand, presented in Figure 2-5, totaled

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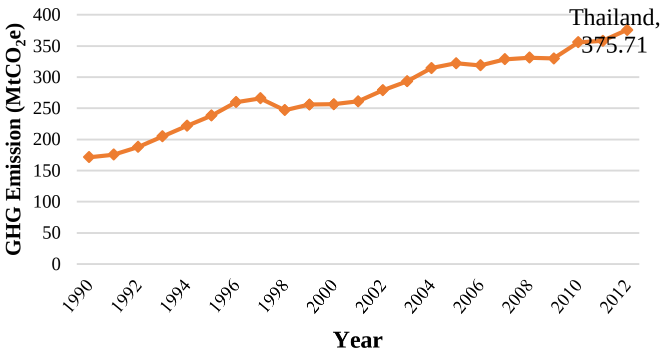
[4] GHG in this study does not include nitrogen trifluoride (NF_3), which was added to the list of GHGs in the second Kyoto compliance period.

[5] Non-Annex I countries are not bound by obligations for GHG emissions mitigation like countries in Annex I and II, but they are encouraged to reduce GHG emissions. At present, there are 153 non-Annex I parties, including Thailand.

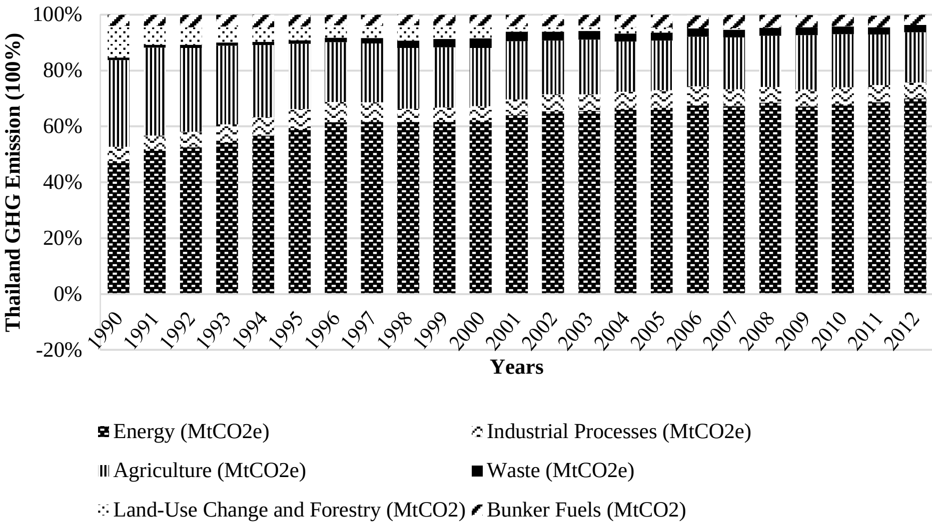
375.71 million tons of carbon dioxide equivalent ($MtCO_2e$) in 2012, which is more than double the volume of GHG emissions in 1990. In addition, it is important to note that, considered at the city level, Bangkok was the 22nd largest emitter in the world and the 5th largest emitter in East Asia in 2010.

Figure 2-5: GHG Emission of Thailand



Source: Climate Analysis Indicators Tool (CAIT), World Resources Institute. (Data are derived on 15 July 2015)

Figure 2-6: Thailand GHG Emission from Different Sources



Source: Climate Analysis Indicators Tool (CAIT), World Resources Institute (Data are derived on 15 July 2015)

Thailand GHG emissions from different sources are presented in Figure 2-6. Approximately 70% of total national emissions originate from the energy sector. This relates to the energy consumed in transportation and electricity generation. Industrial production processes and agricultural activities contribute to GHG emissions to some extent. To clearly understand the characteristics of GHG emissions in Thailand, the national GHG inventory officially reported in Thailand's Second National Communications to the UNFCCC is taken into account.[6] Table 2-2 demonstrates total emissions classified by type of GHG. It shows that the energy and industrial sectors are sources of CO and CO_2 emissions, whereas the agricultural sector is a source of CH_4 emission.

Table 2-2: Total Emissions Classified by Type of GHG

Main GHG	CO_2 Emissions (Gg)	CO_2 Removals (Gg)	CH4 (Gg)	N2O (Gg)
Total National Emissions and Removals	210231.20	-52374.00	2801.50	40.00
Energy	149914.60	0.00	413.90	2.50
Industrial Processes	16059.30	0.00	6.40	0.60
Agriculture			1977.00	33.40
Land Use Change and Forestry	44234.10	-52,374.00	10.40	0.10
Waste	23.30		393.80	3.30

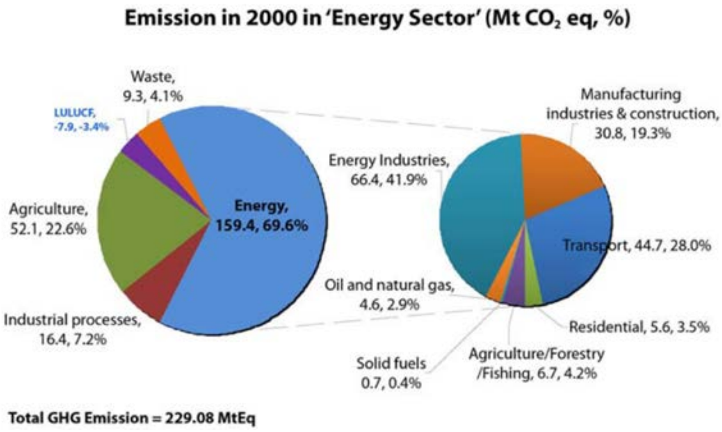
Source: Thailand's Second National Communications to the UNFCCC (2005)
Note: Data of the national GHG inventory for 2000
Gg denotes thousand tons or gigagrams

Figure 2-7 illustrates emissions from the energy sector. Energy industries (including electricity) are the largest contributors of emissions from the energy sector, followed by the transportation sector, and manufacturing industries and construction sectors. Emissions from these three sources contribute more than 90% of total emissions from the energy sector. Focusing on the emissions from industrial processes in Figure 2-8, emissions from industrial processes come from the manufacture of mineral products, including cement, lime, dolomite, and soda ash. This contributes about 97.9% of total emissions from industrial processes. The chemical industry and metal production are also sources of emissions.

[6] Developing countries that signed the UNFCCC are required to submit National Communications (NCs) under an agreement of the principle of applying measurement, reporting, and verification (MRV).

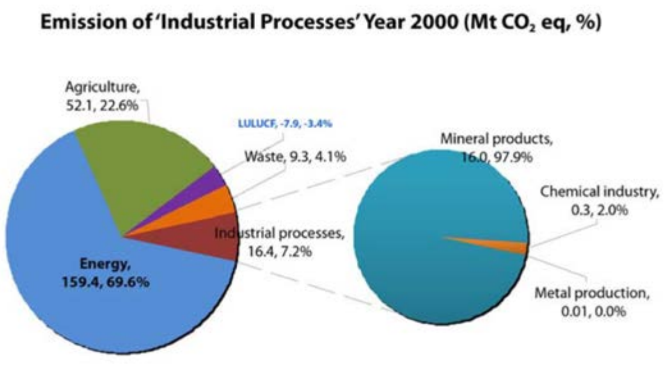
In summary, emissions statistics show that in Thailand, manufacturing is closely linked with GHG emissions, directly through industrial processes and indirectly through energy consumption in industrial production. This knowledge supports the previously proposed idea that an expansion of industry in Thailand will increase GHG emissions.

Figure 2-7: Emissions from the Energy Sector in CO_2 Equivalent



Source: Thailand's Second National Communications to the UNFCCC (2005)
Note: Data of the national GHG inventory for 2000

Figure 2-8: Emissions from the Industrial Sector in CO_2 Equivalent



Source: Thailand's Second National Communications to the UNFCCC (2005)
Note: Data of the national GHG inventory for 2000

With regard to environmental policy, Thailand does not have stringent environmental measures that deal with pollution and GHG emissions. This is because Thai policymakers focused on increasing national income and accelerating economic growth during the rapid growth period, environmental issues were not particularly emphasized.

There are two primary environmental laws: the Enhancement and Conservation of National Environmental Quality Act, B.E. 2535; and Article 67 of the Thai Constitution. Under the first, the Environmental Quality Board was established. The Environmental Quality Board has the power and duty to submit policy and govern agencies related to environmental quality management. Article 67 of the Thai Constitution stipulates that environmental impact assessments must be conducted before large-scale development projects start. These laws set environmental standards such as water quality standards (2009), air quality and noise standards (2007), and soil quality standards (2004).

With regard to GHG emissions, as a UNFCCC Non-Annex I member, Thailand does not have an obligation to cut emissions; implementing a policy to reduce GHG emissions is voluntary, not mandatory. However, the rapid growth in awareness of climate change and global warming, both in the global community and at the national level, puts pressure on Thailand. To cope with climate change concerns, the Thai government has planned to impose various policies and actions. Climate change was mentioned in the 7th National Development plan (1992-1996) but was not a central dialogue. A significant step in climate change mitigation started when Thailand decided to shift its development goals from economic growth to sustainable development. Sustainable development was promoted in the 9th National Economic and Social Development plan (2002-2009), but no practical measures for GHG emissions were imposed at that time. The 11th National Economic and Social Development plan (2012-2016) highlights the need for the country to transition to a green economy and society. A central message is encouraging green production and consumption.

Apart from the dialogue in the National Economic and Social Development plan, the National Strategy for Climate Change Management (2008-2012) was announced by the Office of Natural Resources and Environment Policy and Planning (ONEP), Ministry of Natural

Resources and Environment. This plan highlights the need to establish basic infrastructures to mitigate GHG emissions, including gathering data and related knowledge, and cooperating with global partners. The ONEP also established the Climate Change Master Plan (2012-2050), composed of three schemes: mitigation of GHG emissions and increase of GHG sinks; strengthening the capacity of human resources and institutions for risk management of the effects of climate change; adaptation for coping with the negative effects of climate change. The National Economic and Social Development Board (NESDB) introduced “a master plan on climate change in Thailand, 2010-2050: energy prices and food security”, proposing various economic measures for dealing with climate change (United Nations Development Programme, 2012).

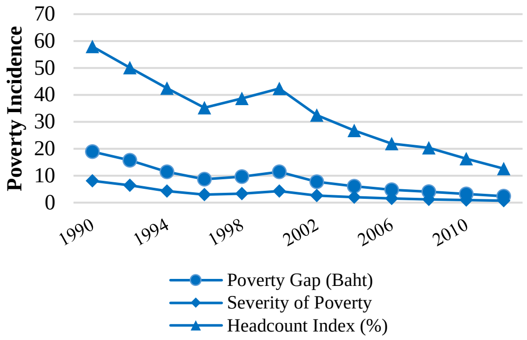
At the moment, environmental policy (including climate change policy) in Thailand is enforced using command and control measures. Market-based measures such as a pollution surcharge and carbon tax are scheduled to launch shortly. Thailand is working on the Financial Measures for Environment Act. Under this law, emissions charges will be levied for pollution such as wastewater and air pollution. Although no new tax levies on GHG emissions will be introduced, but a carbon tax system is emphasized in the Climate Change Master Plan by the NESDB, as mentioned above.

2.5 Poverty Incidence in Thailand

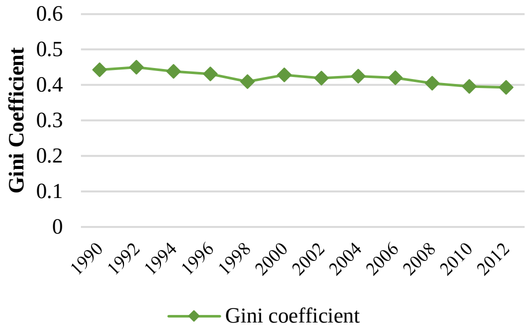
When a macroeconomic policy is imposed, particularly a policy that creates an effect on economic growth, it usually has an impact on poverty and income distribution. As pointed out in Section 2.2 and Section 2.3 , trade policy is promoted to drive economic growth in Thailand; therefore, it is rational to anticipate that trade policy will affect poverty and income distribution in Thailand. If a carbon tax is introduced, as mentioned in previous section, it will affect poverty and income distribution as well. Thus, a discussion of poverty and inequality issues is pertinent.

Income distribution, represented by the Gini index[7], and the incidence of poverty in Thailand are presented in Figure 2-9. In Figure 2-9(a), poverty incidence from 1990 to 2014 is presented. There are three indexes, including the poverty gap, the severity of poverty, and a headcount index. The headcount index measures the proportion of the population that is poor. Poor refers to individuals whose income is below the poverty line. The poverty gap measures the extent to which individuals fall below the poverty line as a proportion of the poverty threshold. It indicates the minimum amount of income transfer needed to bring the poor out of the poverty. The poverty severity index is an average of the squares of the poverty gaps relative to the poverty line. This index indicates the degree of inequality among the poor (World Bank, 2014).

Figure 2-9: Poverty Incidences and Gini Index



(a) The Incidences of Poverty



(b) Income Distribution

Source: The National Economic and Social Development Board (Data extracted on 15 July 2015)

[7] Gini index measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. Gini index measures the area between the Lorenz curve and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. Thus a Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality (World Bank, 2014).

The poverty indexes continuously declined during the study period. The headcount index shows an impressive reduction. It declined from 57.97% in 1990 to 12.64% in 2012. The poverty gap ratio reveal similar trends. It declined from 18.99 in 1990 to 2.38 in 2012. The severity of poverty also dropped from 8.11 in 1990 to 0.17 in 2012. Considering the correlation between poverty incidences and macro policy, it can be roughly stated that the poverty of Thailand declined during the period of the export promotion policy.

Although the rapid economic growth had a positive impact on poverty, income distribution showed a trivial change. The Gini coefficient presented in Figure 2-9(b) demonstrates that income distribution gradually changed between 1990 and 2012. It seems that Thailand was not successful in changing the distribution of income. Roughly speaking, although the export promotion policy was beneficial with respect to poverty alleviation, it did not significantly decrease income inequality. Hence, it is interesting to explore how trade reform policy, which may increase imports and exports, affects poverty and income distribution in Thailand.

For carbon tax, since the carbon tax have not been imposed yet, there is no statistical data to describe the impact of a carbon tax on poverty and income distribution in Thailand. However, an implementation of the carbon tax, theoretically, would redistribute returns for factor inputs and then household income. Therefore, it is expected to affect poverty and income distribution, too.

Chapter 3: Data and Methodology

This chapter describes the methodology and data used in this study. To begin with, in Section 3.1, the background of the research methodology is discussed. Section 3.2 clarifies the overall research procedure. In short, the analytical method used in this study involves two stages of analysis. The first step is the Computable General Equilibrium (CGE) analysis. The second step is using the results from the CGE analysis to perform a post-simulation analysis. Detailed discussions of the data and the model are presented in Section 3.3 to Section 3.6.

3.1 Brief Discussion on Methodology

To capture the impacts of trade reform on GHG emissions and poverty incidence, there are numerous methods of measurement, such as an input-output analysis, a partial equilibrium analysis using econometrics tools, and a CGE analysis. Selecting a method depends on the objectives of the study and the availability of data.

In studies concerning trade reform, the CGE analysis is frequently chosen (see Acharya, Hölscher, & Perugini, 2012; Chen & Ravallion, 2004; Ezaki & Lin, 2000; Vos & De Jong, 2003). The CGE model is one of the most well-known quantitative methods for evaluating the impacts of public policy on the economy as a whole. An advantage of the CGE analysis is that it illustrates a wide set of economic impacts, as it incorporates the behaviors of multiple interacting agents and multiple markets. For that reason, it contributes distributive effects at different levels of disaggregation. Compared with the other methods mentioned above, the CGE approach eliminates the limitations of the input-output technique by integrating market mechanisms in the analysis and allows tracking of distributional impacts that cannot be captured by partial equilibrium analysis.[8] The CGE analysis is a useful tool for public policy design and implementation, especially when the policy is expected to have significant effects throughout

[8] Partial equilibrium analysis usually refers to an analysis in one independent market, considering other markets and other elements as exogenous.

the economy. Given its advantages, this study applies the CGE method to evaluate the economy-wide impacts of trade reform in Thailand.

To measure the impacts of trade on GHG emissions, an application of CGE modeling has been conducted using various techniques. The Global CGE model, which evaluates the impacts of macroeconomic policy on GHG emissions, is usually applied when global activity is taken into account. The well-known Global CGE model are the GREEN Model pioneered by the Organization for Economic Co-operation and Development (OECD) Secretariat as well as GTAP-E model, which belongs to the Global Trade Analysis Project (GTAP) family of models. A single-country CGE model is widely utilized when the impacts of trade on GHG emissions in a specific country are the focus (see Acharya et al., 2012; Amin et al., 2008; Cororaton & Cockburn, 2007; O'Ryan et al., 2005). GHG emissions can be assessed either endogenously or exogenously in the CGE model. For example, a change in GHG emissions can be measured via the emission equations included in the CGE model, which are usually called an emission block. Alternatively, they can be calculated outside the model by using an emissions coefficient. In this study, considering the model structure and data availability, GHG emissions are calculated exogenously.

To estimate the impacts of trade reform on poverty, the CGE-microsimulation method could be a suitable method for poverty analysis. The CGE-microsimulation technique is efficient for linking macro and micro accounts. In general, trade reform is usually considered at a macro level, while poverty analysis is considered at a micro level. Using only micro models cannot capture changes in poverty incidence due to macroeconomic policies, whereas macro models do not emphasize poverty at the household level. Therefore, the integration between micro and macro models is vital (Robinson et al., 2005).

3.2 Research Framework

Before discussing the model and data used in this study, the comprehensive research framework is presented in this section in order to present the whole picture of the methodology.

Recalling the first research question, the impacts of trade reform on GHG emissions are the main interest. To begin with, the impacts of full trade reform on GHG emissions are examined. When climate change concerns are expressed, this study proposes that Thailand either introduce a carbon tax or reduce the degree of trade openness by using partial trade reform, to avoid an increase in GHG emissions. Hence, secondly, the impacts of partial trade reform on GHG emissions are explored. Carbon taxes are considered as means for minimizing the increase in GHG emissions due to free trade. They are combined with full trade reform to represent trade policy with climate change considerations. In total, six policy scenarios relating to free trade and carbon taxes are considered in this study. Scenario 1 is a simulation of full trade reform. Scenario 2 is a simulation of trade reform policy in carbon intensive sectors or the partial trade reform. Scenario 3 is a simulation of the lax carbon tax without trade reform. Scenario 4 represents a simulation of the strict carbon tax without trade reform. Scenario 5 addresses a simulation of full trade reform with lax carbon tax. Scenario 6 is a simulation of mixed policy of full trade reform and strict carbon tax. Simulation design will be discussed in details in section 3.5.

To achieve the research objectives, two steps are required in the analysis. In the first step, the CGE analysis technique is utilized to simulate six policy scenarios. Data used for the CGE analysis are from the Thailand Social Accounting Matrix (SAM). Results from the CGE analysis illustrate economy-wide impacts such as changes in prices, production, factor returns, etc.

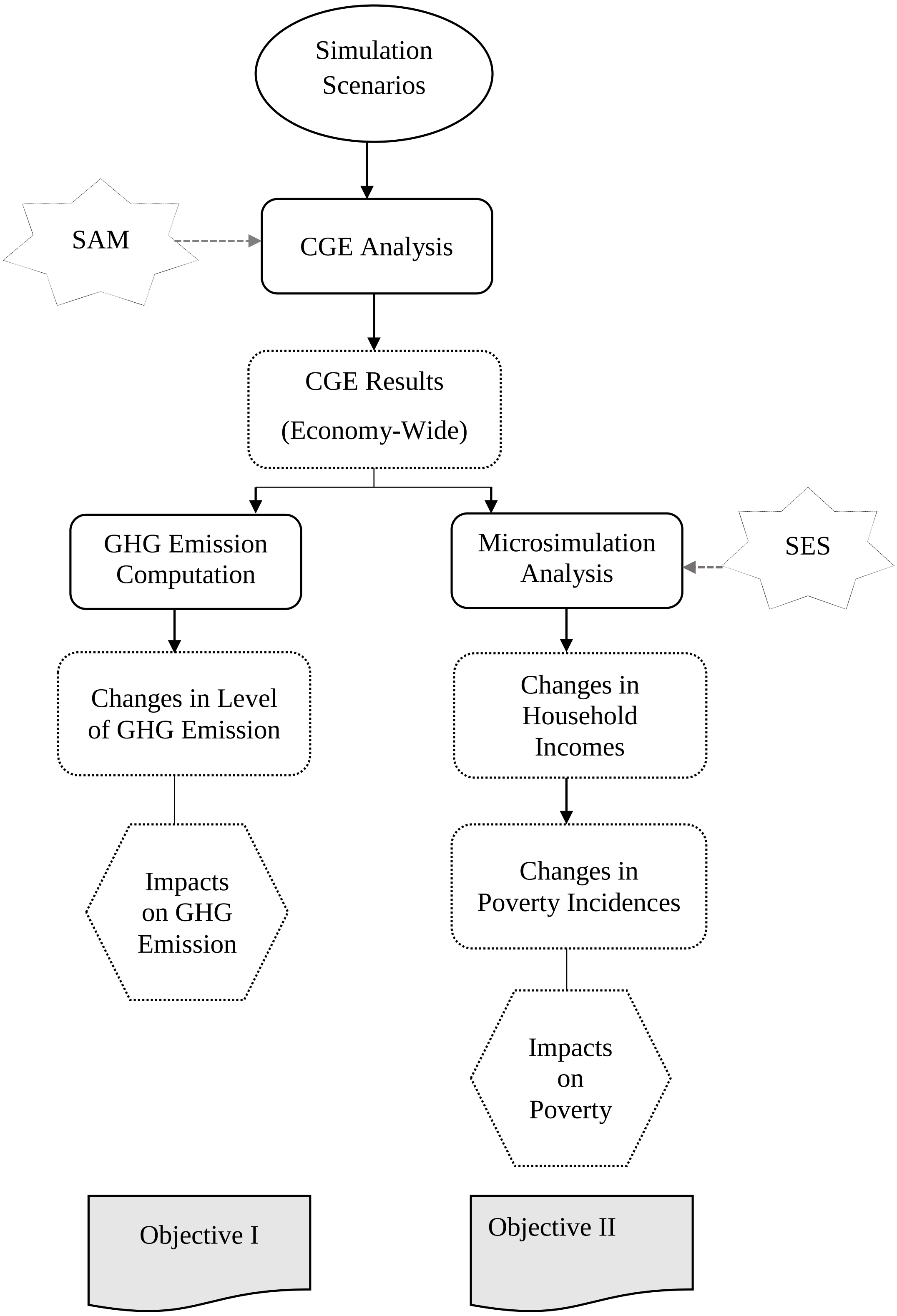
Changes in GHG emissions under the six policy scenarios cannot be detected directly from the CGE results. A second step that utilizes the outcomes from the CGE analysis to calculate changes in the level of GHG emissions is necessary. In this study, GHG emissions are examined with reference to final consumption and domestic production. The level of final consumption from the CGE analysis and the GHG sectoral emissions coefficient are utilized to observe changes in the level of GHG emissions in all policy scenarios. The level of domestic production is used to calculate the scale and composition effects in order to understand a change in economic structure.

Another research objective is measuring the impacts of the six policy scenarios on social issues, in particular, poverty and income distribution issues. To investigate the impacts on poverty and income distribution, the calculation procedure is similar to the process for the first objective. First, the CGE analysis is applied. Then, its results are utilized in the second step to assess changes in poverty and income distribution indicators using a microsimulation technique. Microsimulation is a modeling technique that operates at the level of individual units. This method is beneficial because it gives highly detailed results that the CGE analysis cannot capture.

A combination of a CGE analysis and a microsimulation is well known as the CGE-microsimulation method (see Cororaton & Cockburn, 2007; Robinson, Yúnez-Naude, Hinojosa-Ojeda, Lewis, & Devarajan, 1999; Savard, 2003; Vos & De Jong, 2003). The results of the CGE analysis can be integrated with the microsimulation analysis in several manners. In this study, changes in the price of goods sold in the domestic market and returns on the factor of production from the CGE analysis are merged with household revenues and expenditures. A net change in household income is then used to calculate changes in poverty incidence and income distribution under six policy scenarios mentioned earlier. Note that the microsimulation requires disaggregated data. In this study, the Household Socio-Economic Survey (SES) data of Thailand is employed.

Figure 3-1 simplifies the methodology described above. A comprehensive discussion of the CGE model and the data is also provided in the following sections. Section 3.3 explains the general concept of a social accounting matrix. Thailand's SAM is also presented. A standard CGE model, the core model for the CGE analysis, is explicated in Section 3.4. The simulation design is described in Section 3.5. In Section 3.6, the microsimulation data are discussed.

Figure 3-1: Research Framework



Source: Author's compilation

3.3 Thailand Social Accounting Matrix

A social accounting matrix (SAM) is a square matrix that represents a comprehensive picture of the economy of a nation. It records the transactions that take place during an accounting period. It consists of row and column accounts representing the various sectors, agents, and institutions of an economy. The transactions are shown in cells. Each cell of the SAM refers to a payment from the account of its column to the account of its row. Hence, the incomes of an account appear along its row and its expenditures appear along its column (Löfgren, Harris, & Robinson, 2001). In the SAM, total revenue (row total) should be equal to total expenditure (column total), which is known as double-entry accounting.

The concepts and structure of the standard SAM are summarized in Table 3-1. The standard SAM differentiates between "activities" and "commodities." Activity accounts are the entities that carry out production, while commodity accounts represent activity outputs. In this way, it is possible that an activity can produce multiple commodities. For instance, an activity can produce a good and its byproducts. Analogously, any commodity can be generated by multiple activities. In the activity columns, payments to a commodity are intermediate inputs. The activities also distribute wages and rents to factors employed in the production process. Taxes are paid to the government. In the commodity columns, payments are made to domestic activities, the rest of the world, and the government. Factors devote payments to households, enterprise, and the rest of the world as a factor income, as well as to the government in terms of taxes. For domestic institutions, households and government pay for commodities. Transfers exist among institutions. Domestic institutions also have savings. The rest of the world pays for purchasing export goods and earns from selling import goods. The rest of the world's savings are addressed as foreign savings.

The Social Accounting Matrix of Thailand is extracted from the database of the Global Trade Analysis Project (GTAP), version 8, following the method of McDonald and Thierfelder (2004). Thailand's data from the GTAP8 is determined with reference to Thailand's 2005 Input-

Output table from the National Economic and Social Development Board (NESDB) and macroeconomic data from 2004 and 2007.

Raw data acquired from this method is from a global SAM, which required additional treatment to reduce it to Thailand's SAM, so its elements are consistent with the IFPRI's CGE model. The pool of income in the GTAP model (payment to/from "Regional Household,") is disaggregated, and an "Enterprise" institution is founded. A transfer between domestic institutions is established by referring to transfer to total income proportion from Thailand's SAM 1998 by Jennifer Ching Li (2002). Thailand's SAM used in this study is shown in Table 3-2. Note that Table 3-2 simply presents Thailand's SAM at an aggregate level. However, it captures the essential features of the SAM.

The sectors in the GTAP database are aggregated to 36 sectors in Thailand's SAM, consisting of four primary agricultural sectors, six resource-based sectors, four agro-industry sectors, four light manufacturing sectors, eight heavy manufacturing sectors, three utility sectors, six service sectors, and a transportation sector. Details of the sectors are presented in Table 3-3.

Production factors in this SAM are labor, capital, natural resources, and land. Labor is classified by skill types and sectors. Labor is classified as unskilled agricultural labor, skilled agricultural labor, unskilled non-agricultural labor, and skilled non-agricultural labor. Capital is classified by sectors and is divided into non-agricultural capital and agricultural capital.

Table 3-1: The Basic SAM Structure

				Expenditures					
Receipts	**Activities**	**Commodities**	**Factors**	**Household**	**Enterprises**	**Government**	**Savings-Investment**	**ROW**	**Total**
Activities		Marketed Outputs		Home-Consumed Outputs					Activity Income (Gross Output)
Commodities	Intermediate Inputs	Transaction Costs		Private Consumption		Government Consumption	Investment	Exports	Demand
Factors	Value-Added							Factor Income From ROW	Factor Income
Household			Factor Income to Households	Interhousehold Transfers	Surplus to Households	Transfers to Households		Transfers to Households From ROW	Household Income
Enterprises			Factor Income to Enterprises			Transfers to Enterprises		Transfers to Enterprises From ROW	Enterprises Income
Government	Producer Taxes, Value-Added Taxes	Sale Taxes, Tariffs, Export Taxes	Factor Income to Government, Factor Taxes	Transfers to Government, Direct Taxes	Surplus to Government, Direct Enterprise Taxes			Transfers to Government From ROW	Government Income
Savings-Investment				Household Savings	Enterprise Savings	Government Savings		Foreign Savings	Saving
ROW		Imports	Factor Income to ROW		Surplus to ROW	Government Transfers to ROW			Foreign Exchange Outflow
Total	Activity	Supply Expenditures	Factor Expenditures	Household Expenditures	Enterprise Expenditures	Government Expenditures	Investment	Foreign Exchange Inflow	

Source: Löfgren et al. (2001)

Table 3-2: Thailand Social Accounting Matrix

	Activities	Commodities	Factors	Household	Enterprises	Government	Capital	ROW	Total
Activities		22,526,835.60							22,526,835.60
Commodities	13,318,074.00			5,081,400.15		1,158,308.43	2,508,817.42	7,204,955.28	29,271,555.27
Factors	9,089,777.72								9,089,777.72
Household			5,896,026.09		273,274.18	71,567.45		120,047.34	6,360,915.06
Enterprises			2,701,253.32			31,489.68			2,732,743.00
Government	118,983.87	742,350.88	492,499.60	62,849.82	47,080.15				1,463,764.33
Capital				1,216,665.27	1,629,024.35	202,398.52		- 539,272.60	2,508,815.53
ROW		6,002,366.90			783,363.11				6,785,730.02
Total	22,526,835.60	29,271,553.39	9,089,779.01	6,360,915.23	2,732,741.79	1,463,764.08	2,508,817.42	6,785,730.02	

Unit: Million Baht (Exchange Rate 40.27 Baht/ US$ at 2005)
Source: Author extract data from the database of the Global Trade Analysis Project (GTAP)

Table 3-3: Mapping of Sectors of Thailand's SAM and GTAP Commodities

Sector	GTAP Commodities
Total	
Primary Agriculture	
Crops	Paddy Rice, Wheat, Cereal Grains N.E.C., Oilseeds, Plant-Based Fibers, Crops N.E.C.
Vegetable and Fruit	Vegetables, Fruit, Nuts
Sugar Cane	Sugar Cane, Sugar Beet
Livestock	Bovine Cattle, Sheep and Goats, Animal Products N.E.C., Raw Milk, Wool, Silkworm Cocoons
Resource-Based	
Forestry	Forestry
Fishing	Fishing
Coal	Coal
Oil	Oil
Gas	Gas
Mining	Minerals n.e.c.
Agro-Industry	
Meat Products	Bovine Meat Products, Meat Products n.e.c.
Food Products	Vegetable Oils and Fats, Food Products n.e.c., Processed Rice, Sugar
Dairy Products	Dairy Products
Beverages and Tobacco	Beverages and Tobacco
Light Manufacturing	
Textile and Apparel	Textiles, Wearing Apparel
Leather Products	Leather Products
Wood Products	Wood Products
Paper and Publishing	Paper Products, Publishing
Heavy Manufacturing	
Petroleum and Coal	Petroleum, Coal Products
Chemical, Rubber, Plastic	Chemical, Rubber, Plastic Products
Non-Metal Product	Mineral Products n.e.c.
Metal Product	Ferrous Metals, Metals n.e.c., Metal Products
Transport Equipment	Motor Vehicles and Parts, Transport Equipment n.e.c.
Electronic Equipment	Electronic Equipment
Machinery	Machinery and Equipment n.e.c.
Manufacturing n.e.c.	Manufactures n.e.c.
Utilities	
Electricity	Electricity
Gas Manufacturing	Gas Manufacture, Gas Distribution
Water	Water
Transportation	Water Transport, Air Transport, Transport n.e.c.

Sector	GTAP Commodities
Services	
Construction	Construction
Trade and Financial Service	Trade, Financial Services n.e.c., Insurance, Business Services n.e.c.
Communication	Communication
Recreation	Recreational and Other Services
Public Services	Public Administration, Defense, Education,
Dwellings	Dwellings

Source: Author compile data from the database of the Global Trade Analysis Project (GTAP)

3.4 The CGE Model

As discussed above, this study's analysis has two steps. The first step is the CGE analysis, which is applied to simulate the economy-wide impacts of full trade reform and five other scenarios. The second step results from the CGE analysis and is a calculation of the impacts of each policy scenario on GHG emissions (Chapter 4) as well as on poverty and income distribution (Chapter 5). Details of the calculation method in the second step will be explained in the corresponding chapter. In this section, the CGE model employed in the first step is described.

Technically, the CGE model provides a sketch of an economy by using a set of non-linear simultaneous inter-linkage equations. The CGE model used in this study closely follows the specifications of the Standard Computable General Equilibrium model of the International Food Policy Research Institute (IFPRI) pioneered by Löfgren et al.(2001).[9] The model is a single country, comparative static general equilibrium model with perfect competition market and constant return to scale technology assumption. The model is composed of the following elements: production (activities and commodities), factor input (labor, capital, land, and natural resources), institutions (household, government, and enterprise), and savings-investments (S-

[9] The mathematical model statement of the Standard Computable General Equilibrium model is presented as a set of simultaneous equations in Appendix A.

I), tax elements, and the rest of the world. The components of the model correspond with the SAM discussed in the previous section.

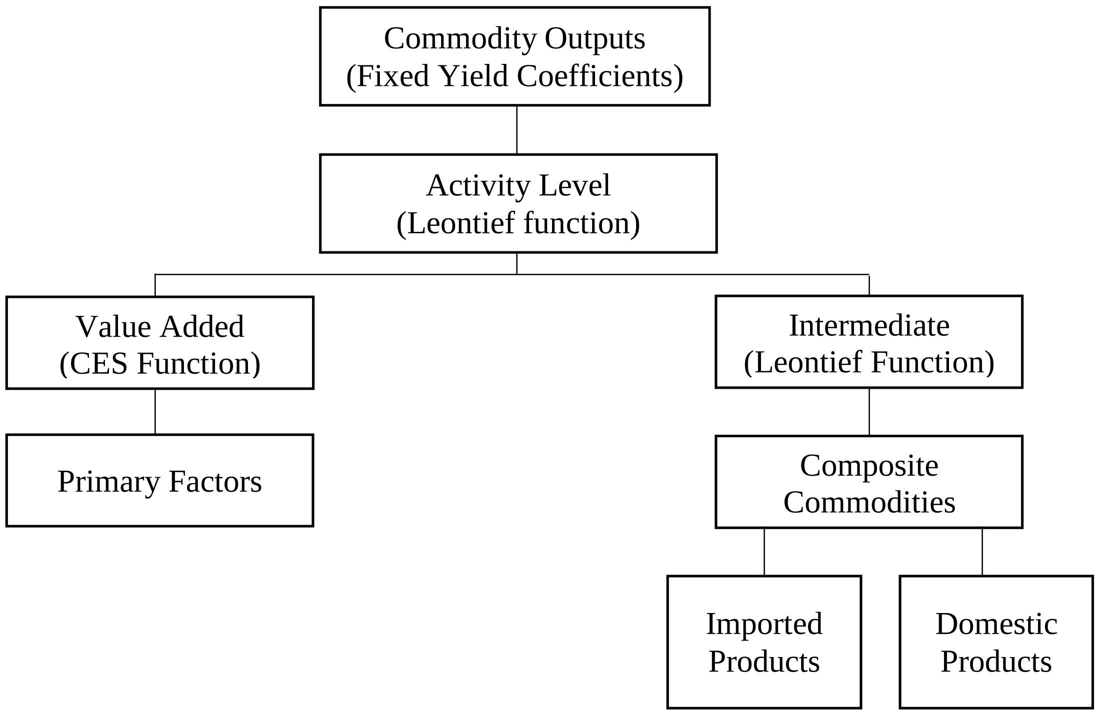
Recalling that there is a difference between "activity" and "commodity," the model assumes that each activity produces a commodity according to a fixed yield coefficient. A producer (represented by an activity) is assumed to maximize profit subject to the cost of factors and intermediate inputs by choosing a combination of intermediate inputs and primary factors. Primary factors in this study include labor, capital, natural resources, and land, which are categorized by skill types or sectors, as discussed above. Intermediate inputs are inputs from the 36 sectors of the SAM. Producer profit is subject to production technology. There are two technology levels. At the top level, technology is assumed to follow the Leontief function of value added and aggregate intermediate input, which implies that, with this technology, value added and aggregate intermediate input are used in fixed proportions and cannot substitute for each other. At the bottom level, value added, defined as an aggregate of primary input factors, is specified as Constant Elasticity of Substitution (CES) technology, which means that there is a constant percentage change in factor proportions as a result of a percentage change in the marginal rate of technical substitution of the factors. For intermediate inputs, the substitution among intermediate inputs is assumed to follow the Leontief specification. Each activity uses a set of factors up to the point where the marginal revenue product of each factor is equal to its factor prices. Imports and output sold domestically are imperfect substitutions and are captured by an Armington function.[10] Figure3.2 shows the production technology of the model that has been discussed above.

This study assumes that the factor market is in equilibrium. There is no factor market segmentation or unemployment. Factor supply is considered as fixed because of the short-run analysis. With regard to wage adjustment, the demand for market factors is equal to the supply

[10] The Armington function refers to a CES function that is limited to commodities that are both imported and produced domestically.

of factors. All types of labor are assumed to be fully employed and mobile, but capital, natural resources, and land are fully employed and activity-specific.

Figure 3-2: Production Technology



Source: Löfgren et al. (2001)

There are four institutions in the model, households, enterprises, the government, and the rest of the world. The household's incomes are from factor returns and transfers from other institutions. Household's expenditures comprise spending for consumption, saving, the direct tax and transfers to other institutions. The character of enterprises is the same as the households except consumption. Enterprises do not consume. For the government, they collect revenue from taxes and transfers from other institutions and allocate it to consumption and transfer to other institutions. Government saving is a flexible residual. The rest of the world transfers payment with domestic institutions. Foreign saving is a difference between foreign currency receipts and spending.

Figure 3-3 presents a flows diagram of the market commodity.[11] The aggregate output of each commodity is defined as a gathering of commodity output of different activities. Under the CES function of aggregate output, the commodity outputs from activities are imperfectly substitution. Supplier minimizes the cost of supplying given the level of aggregate output. The aggregate output can be allocated to domestic and export markets, subject to an imperfect transformability expressed by a constant elasticity of transformation function, with an assumption that suppliers maximize sale revenues.

In the domestic markets, there is a composite commodity that consists of imports and aggregate outputs sold domestically subject to the CES function. Export supplies of the rest of the world are infinitely elastic. In the domestic market, the demand for composite commodity is made up of the sum of demands from two domestic institutions (households and government), demand from activities as intermediate inputs, and demand from investment.

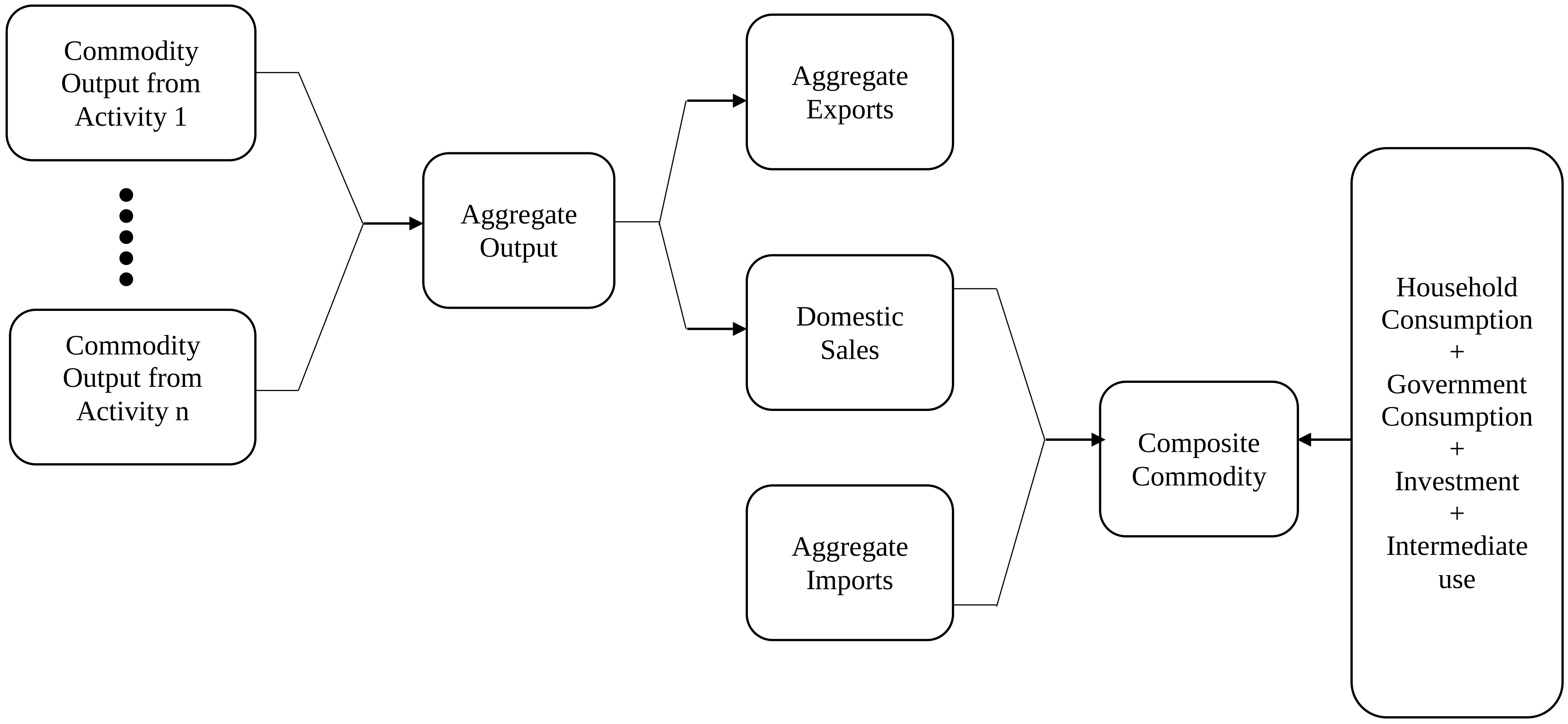
Model closures for this study are chosen as follows. Macroeconomic balance are chosen by concerning the stylize facts and following the assumption that Thai economy is a small and open economy. For government balance, government saving is flexible, all tax rates and the government consumption are fixed. For the external balance, as Thailand currently apply a floating exchange rate system, exchange rate is considered as flexible while foreign savings is fixed. For the saving-investment balance, the selected closure is an investment-driven type of closure which the value of saving is an adjustment. The consumer price index is chosen to be numeraire. With those selected closures, it can be said that the study applies "Johansen Closure" which is suitable for the study as it can exclude intertemporal impacts from variation in some economic attributes. Since this study examines impacts of several policies only in one single period, any variables contribute significant impacts in multiple periods and can make

[11] An explanation of the diagram is a basic concept of flows of output. Transaction cost, transportation cost, tariff and other related-distortion are not addressed here. For detailed expression, see Löfgren, Harris, & Robinson (2001)

bias to the results should be avoided. For instance, impacts from foreign saving and real investment have intertemporal effect beyond the period of this study. Rising in household's income from an increase in foreign saving may raise household's welfare for the first period, but households have to suffer from foreign debt in the second period. This situation should be avoided as it can cause bias to the household welfare in the study period.

In order to calibrate the standard CGE model explained above, the General Algebraic Modeling System (GAMS), a software application for mathematical programming and optimization, is used with the Thailand SAM. The data set used for elasticity in the model is taken from the GTAP8. Once the model is calibrated and solved, the GAMS software is used to calibrate the simulations to observe the economy's response. Outlines of the simulations in this study are presented in the next section.

Figure 3-3: Flows of Marketed Commodities



Source: Löfgren et al. (2001)

3.5 Simulation Design

In this section, the simulation scenarios in this study are explained. To capture the impacts of trade reform on GHG emissions, which is the main objective of this study, two forms of trade reform are considered: full trade reform and partial trade reform. In full trade reform, the import tariff is set to zero for all import goods. The initial tariff rates for the 36 aggregated sectors are presented in Table 3-4.

The tariff structure is calculated based on Thailand's SAM. The manufacturing n.e.c. group, defined by the UN Statistics Division, includes the manufacture of jewelry, musical instruments, sporting and athletic goods, etc. (United Nations Statistics Division, 2016), and is protected by the largest import tariff. Primary agricultural products such as crops, vegetables and fruits, as well as agro-industry products are highly protected as well. Other manufacturing sectors are protected by tariff to some extent.

To prevent an increase in GHG emissions due to trade reform, this study assumes that Thailand imposes environmental measures to control the level of GHG emissions. Thailand may apply partial trade reform rather than full trade reform or may enforce a domestic carbon tax together with full trade reform.

Partial trade reform is defined as trade reform in carbon-intensive sectors. Specifically, tariffs are completely removed in nine sectors. The carbon-intensive sector is described as a sector with higher than average emissions intensity. As indicated by the GHG emissions intensity rates presented in the third row of Table 3-4, the carbon-intensive sectors of Thailand consist of fishing, mining, textiles and apparel, paper and publishing, chemical, rubber and plastic, non-metal products, and metal products. By applying partial trade reform, Thailand will increase the import of carbon-intensive goods instead of producing them domestically. Roughly speaking, partial trade reform is a tacit environmental protection barrier policy. It is applied with concerns of climate change safeguards more than trade benefits.

Table 3-4: Tariff, GHG Intensity, and the Carbon Tax

Sector	Tariff	GHG Intensity (tCO_2e/ Million Baht)	Lax Carbon Tax Rate (500 Baht/tCO_2e)	Strict Carbon Tax Rate (2500 Baht/tCO_2e)
Primary Agriculture				
Crops	10.87	13.64	0.68	3.41
Vegetable and Fruit	15.09	14.25	0.71	3.56
Sugar Cane	0.00	10.87	0.54	2.72
Livestock	4.60	22.27	1.11	5.57
Resource-based				
Forestry	4.75	8.16	0.41	2.04
Fishing	6.86	60.42	3.02	15.11
Coal	0.79	40.19	2.01	10.05
Oil	0.00	33.71	1.69	8.43
Gas	0.01	33.71	1.69	8.43
Mining	1.00	63.42	3.17	15.86
Agro-industry				
Meat Products	15.60	25.55	1.28	6.39
Food Products	10.72	36.95	1.85	9.24
Dairy Products	9.33	35.36	1.77	8.84
Beverages and Tobacco	42.60	22.84	1.14	5.71
Light Manufacturing				
Textile and Apparel	9.49	46.60	2.33	11.65
Leather Products	13.73	30.05	1.50	7.51
Wood Products	8.70	25.10	1.26	6.28
Paper and Publishing	4.88	52.61	2.63	13.15
Heavy Manufacturing				
Petroleum and Coal	7.84	28.48	1.42	7.12
Chemical, Rubber, Plastic	8.63	54.27	2.71	13.57
Non-Metal Product	12.19	207.79	10.39	51.95
Metal Product	4.04	110.41	5.52	27.60
Transport Equipment	18.60	35.28	1.76	8.82
Electronic Equipment	1.75	34.24	1.71	8.56
Machinery	5.10	20.85	1.04	5.21
Manufacturing n.e.c.	55.26	38.10	1.91	9.53
Utilities				
Electricity		288.41	14.42	72.10
Gas Manufacturing		30.26	1.51	7.57
Water		41.45	2.07	10.36
Transportation		100.21	5.01	25.05
Services				
Construction		64.06	3.20	16.01

Sector	Tariff	GHG Intensity (tCO2e/ Million Baht)	Lax Carbon Tax Rate (500 Baht/tCO2e)	Strict Carbon Tax Rate (2500 Baht/tCO2e)
Trade and Financial Service		17.25	0.86	4.31
Communication		8.46	0.42	2.12
Recreation		29.59	1.48	7.40
Public Services		16.41	0.82	4.10
Dwellings		5.86	0.29	1.47

Source: Author's calculation from Thailand SAM and Limmeechokchai & Suksuntornsiri (2007)

Another environmental measure, the carbon tax, is designed by referring to previous literature (see Tantivasadakarn, 2010; Wattanakuljarus & Wongsa, 2011). The carbon tax is set at two levels: a lax carbon tax with 500 Thai Baht per ton of carbon-dioxide equivalent (tCO_2e) emissions, and a strict carbon tax with 2,500 Thai Baht per tCO_2e of emissions.[12] Carbon tax rates are presented in Table 3-4. To integrate the carbon tax with the CGE model, carbon tax is converted into an ad-valorem tax following the method applied in McDougall (1993) and Wattanakuljarus & Wongsa (2011). Note that a comparison between the effectiveness of the carbon tax and partial trade reform is worthwhile for its implications on policy.

The simulations are designed based on the study's objectives. First of all, the base year reveals the benchmark scenario in the absence of trade reform or environmental policies. For policy simulation, there are six scenarios in this study. Scenario 1, full trade reform, is a simulation of trade reform implemented across the sector without any carbon taxes. Simulation results for Scenario 1 answer the research question *"How does trade reform affect GHG emissions in Thailand?"* Scenario 2 is a simulation of trade reform policy in carbon-intensive sectors only, or partial trade reform. The simulation results for this scenario can be compared with Scenario 1 to find out whether Thailand should introduce full trade reform or partial trade reform. The result can also indicate the effectiveness of trade policy with regard to climate change concerns. Scenario 3 is a simulation of a lax carbon tax without trade reform. Scenario

[12] Lax carbon tax is US$14.68 per tCO_2e, and strict carbon tax is US$73.42 per tCO_2e (Exchange Rate 34.05 Baht/US$ at July 2015)

4 is a simulation of a strict carbon tax without trade reform. Two scenarios for carbon tax are necessary because the simulation results explicitly provide the impacts of implementing a carbon tax. Results are useful both in terms of contributing knowledge about the efficacy of the carbon tax in Thailand and providing a reference for comparisons among the scenarios. Scenario 5 addresses a simulation of full trade reform with lax carbon tax. Scenario 6 considers a mixed policy of full trade reform and strict carbon tax. Scenarios 5 and 6 represent mixed policy involving full trade reform and carbon taxes simultaneously. The results of these two scenarios answer the research question on carbon tax implementation for controlling GHG emissions under free trade. The simulation scenarios are summarized in Table 3-5.

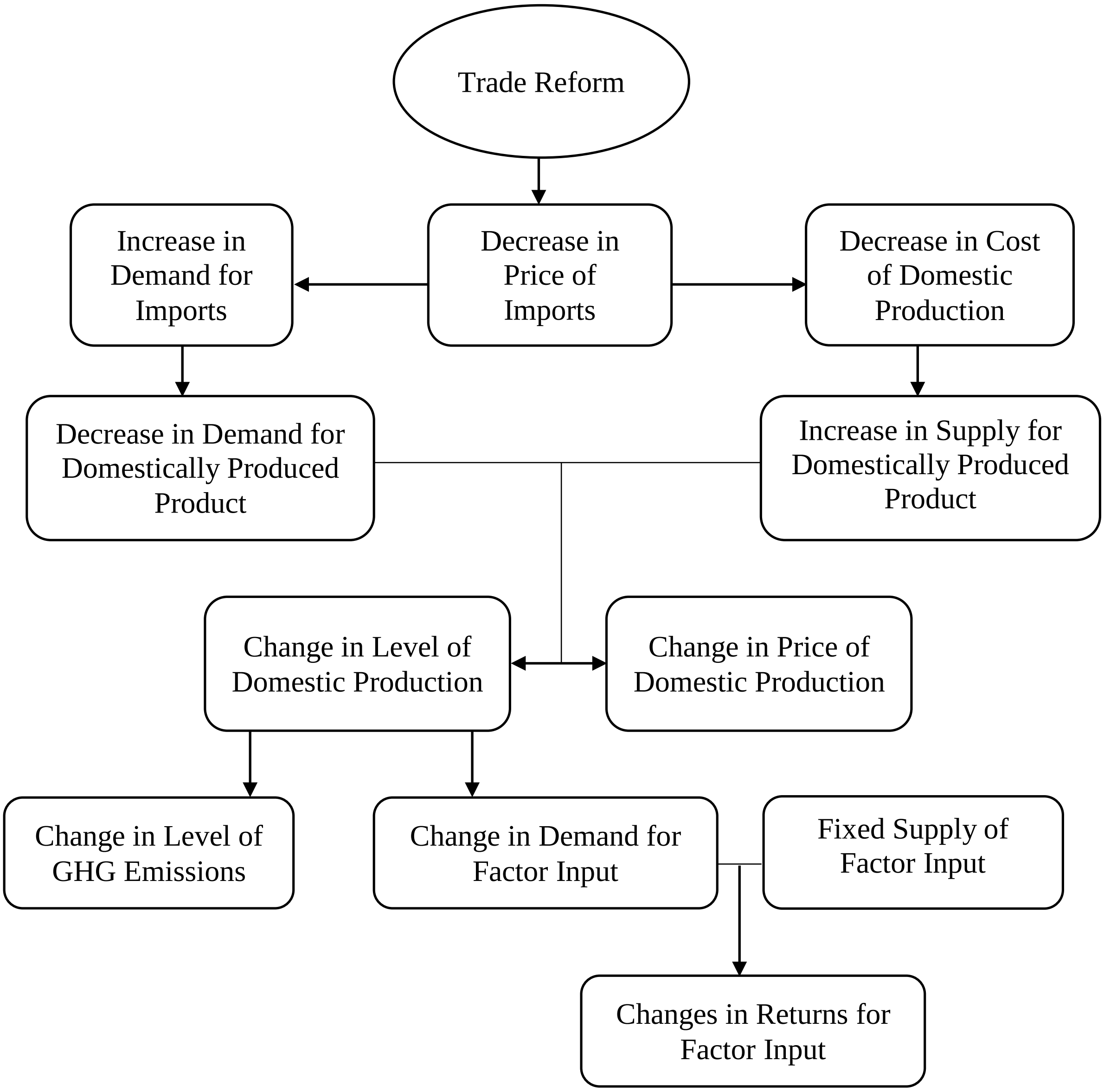
Table 3-5: Simulation Scenarios

	Without Carbon Tax	**Lax Carbon Tax**	**Strict Carbon Tax**
Without Trade Reform	Base Case	Scenario 3	Scenario 4
With Full Trade Reform	Scenario 1	Scenario 5	Scenario 6
With Partial Trade Reform	Scenario 2		

Source: Author's compilation

The standard CGE model explained in Section 3.4 is calibrated for simulations under all of the above scenarios, and the results are then compared with those in the base case. Theoretically, with trade reform, the domestic prices of imported goods decline. On the demand side, demand for imported goods increases, while demand for domestically produced goods decreases. The size of the change depends on the marginal rate of substitution between two goods. On the supply side, tariff removal leads to a reduction in production costs, which increases the supply of domestic goods. A total change in domestic production depends on the net effect of these demand and supply impacts. A mechanism for an adjustment of the economy is presented in Figure 3-4. Note that changes in domestic production lead to changes in returns on factors of production, which will be used for an analysis of poverty in Chapter 5. The levels of final demand under different scenarios are used to estimate GHG emissions in Chapter 4. Details of the calculation methods will be clarified in each corresponding chapter.

Figure 3-4: An Adjustment of Economy after Trade Reform



Source: Author's compilation

It is often the case that a sufficient expansion in exports due to improved price competitiveness in those expanding sectors is necessary to compensate for the losses in production made in competing import sectors. As a result of all of the above adjustments, the production structure, imports, and exports of the country will also change. A change in the production structure leads to a change in returns to production factors, household income, and consumption. Finally, the gross domestic production (GDP) will change as well. For a larger positive impact from trade reform, more flexible factor markets and resource shifts from shrinking to expanding sectors are required. Assumptions on the marginal rates of substitution between domestic and imported products and rigidities in factor mobility are thus crucial among other parameters.

3.6 Data for the Microsimulations

To find the impacts of trade reform and carbon tax on poverty and income distribution, a top-down microsimulation method is applied. In short, in this study, this method is conducted by linking changes in the selected parameters from the CGE simulation results—returns on production factors, and prices of goods—with micro-level data from households. Details of the microsimulation technique and its analytical results will be discussed comprehensively in Chapter 5.

The data employed in the microsimulation approach is from the Household Socio-Economic Survey (SES) of Thailand. The SES contains household data that includes the following: characteristics of household members, such as sex, age, education, occupation; household incomes and expenditures; housing characteristics; and ownership of household durable goods. The SES data selected for the analysis were gathered by the National Statistical Office (NSO) in 2007, the same period of the macroeconomic data in Thailand's SAM. To illustrate the results of the analysis clearly, a brief discussion of the demographic characteristics of the 2007 SES is addressed.

The survey covered all private, permanent resident, non-institutional households in all provinces, both in municipal and non-municipal areas. It comprised data from 43,055 households. The survey data was collected by interview method. The period of data collection was from January to December 2007.

As the microsimulation experiment is conducted for poverty analysis, the characteristics of the poor household are of interest. Thus, data from poor households are gathered and discussed separately. A poor household is defined as a household with expenditures below the poverty line. From the 43,055 households in the SES, there are 6,947 poor households, which are equal to 16.14% of total households. Table 3-6 provides household data classified by region. It shows that most households in the survey are in the central region (28.85%), the northeast region (26.40%), and the north (24.93%). Poor households are mainly located in the north and northeast regions, and represent 34.88% and 39.74%, respectively, of total poor households in the survey. A total of 61.54% of nationwide households in the survey are in municipal areas, while 38.46% of households are in non-municipal areas. About 61.03% of all households in non-municipal areas are poor, as shown in Table 3-7.

Table 3-6: Household Classified by Regions

Region	All Household	All Household (%)	Poor Household	Poor Household (%)
Bangkok Metropolitan	2451	5.69%	17	0.24%
Central	12421	28.85%	992	14.28%
North	10734	24.93%	2423	34.88%
Northeast	11365	26.40%	2761	39.74%
South	6084	14.13%	754	10.85%
Total	43055	100.00%	6947	100.00%

Source: Author's calculations from the 2007 Household Socio-Economic Survey of Thailand

Table 3-7: Household Classified by Administrative Area

Administrative Area	All Household	All Household (%)	Poor Household	Poor Household (%)
Municipal Areas	26494	61.54%	2707	38.97%
Non-Municipal Areas	16561	38.46%	4240	61.03%
Grand Total	43055	100.00%	6947	100.00%

Source: Author's calculations from the 2007 Household Socio-Economic Survey of Thailand

When households are categorized by socio-economic class (Table 3-8) determined on the basis of occupation type, according to survey results, nationwide households with workers employed as entrepreneurs and merchants dominate the sample by sharing 18.73%. Most of them work in small enterprises or private businesses with no employees. In poor households, which constitute the largest percentage of the total—21.65%—no one holds a permanent job. These households receive social assistance, pensions, and annuities.

Table 3-8: Household Classified by Socio-Economic Classes

	All Household	All Household (%)	Poor Household	Poor Household (%)
Farm Operator who Mainly Owned Land				
Less than 2 Rai	217	0.50%	68	0.98%
2 to 4 Rai and 399 Tarangwa	489	1.14%	191	2.75%
5 to 9 Rai and 399 Tarangwa	1004	2.33%	371	5.34%
10 to 19 Rai and 399 Tarangwa	1476	3.43%	496	7.14%
20 to 29 Rai and 399 Tarangwa	1276	2.96%	393	5.66%
40 Rai or more	570	1.32%	96	1.38%
Farm Operator Who Mainly Rented Land				
Less than 5 Rai	180	0.42%	104	1.50%
5 to 19 Rai and 399 Tarangwa	469	1.09%	196	2.82%
20 Rai or more	625	1.45%	133	1.91%
Fishing, Forestry, Agricultural Services, Etc.	820	1.90%	360	5.18%
Entrepreneurs, Trade And Industry				
With Paid Workers	2020	4.69%	38	0.55%
Without Paid Workers	8065	18.73%	889	12.80%
Professional, Technical And Managerial				
Working on Own Account	57	0.13%	9	0.13%
Employed by Others	5296	12.30%	83	1.19%
Laborers				
Farm Workers	1171	2.72%	400	5.76%
General Workers	387	0.90%	108	1.55%
Other Employees				
Clerical, Sales& Services Workers	6708	15.58%	583	8.39%
Production& Construction Workers	4789	11.12%	884	12.72%
Receiving Social Assistance or Pensions/Annuities	7023	16.31%	1504	21.65%
Receiving Property Income	413	0.96%	41	0.59%
Total	43055	100.00%	6947	100.00%

Source: Author summarizes from the 2007 Household Socio-Economic Survey of Thailand
Note: 1 Rai = 1600 square meter

Considering households engaged in agricultural activity, described in the SES as farm operators, 14.65% of total households have workers in this field. A total of 79.80% of agricultural households own land, mostly from 5 to 30 Rai (usually considered as small-medium farm operators), and 20.20% of them do not own land. Compared with poor households, 29.48% of all households are classified as agricultural households and 21.14% of them do not own their land. It is observed that a high proportion of poor households participate in agricultural activity, about one-third of total poor households, whereas only 14.65% of households nationwide engage in this activity.

Poor households also have workers employed as unskilled labor, such as farm workers and production and construction workers, to a great degree. They rarely have workers in skilled activities such as professional, technical, and managerial jobs. Referring to the survey results, 12.43% of nationwide households have members involved in skilled activities, but only 1.32% of poor households have members employed in such jobs.

With regard to household income and expenditures (Table 3-9), survey results reveal that nationwide households earn on average 17,137.27 baht per month, while poor households earn 5,740.41 Baht per month. Nationwide household incomes are mainly from wages and salaries that are equal to 48.41% of total income. Sources of income in poor households are relatively various, for example, earnings from wages and salaries (37.29%), profits from business (17.79%), profits from farming (25.60%), and assistances from other people outside the household (16.15%). With regard to expenditures, households nationwide spend on average 15,577.42 Baht per month. Of this amount, 31.64% is spent on food and beverages. Considering poor household expenditures, poor household spending averages 6,270.48 Baht per month; 51.25% is spent on food and beverage. The survey results show that the proportion of income that poor households spend on food and beverage is higher compared with households nationwide.

Table 3-9: Household Incomes and Expenditures

	All Household	Poor Household	All Household	Poor Household
	Average		% of Total	
Monthly Expenditure				
Household Total Expenditure	15,577.42	6,270.48		
Household Expenditure on Food, Beverage and Tobacco	4,928.04	3,213.45	31.64	51.25
Monthly Income				
Household Income	17,137.27	5,740.41		
Wage and Salaries	8,296.42	2,140.43	48.41	37.29
Net Profit from Business	4,774.21	1,021.07	27.86	17.79
Net Profit from Farming	1,644.58	1,469.31	9.60	25.60
Income from Pensions and Other Assistance	637.79	22.52	3.72	0.39
Income from Work Compensations or Terminated Payment	15.60	1.08	0.09	0.02
Income from Money Assistance from Other People Outside Household	1,293.20	926.99	7.55	16.15
Income from Elderly and Disability Assistance from Government and Other Organization	68.82	131.32	0.40	2.29
Income from Rent of Accommodation, Land and Properties	192.09	21.99	1.12	0.38
Income from Saving Interests, Shares, Bonds and Stocks	188.66	4.84	1.10	0.08
Income from Lending	25.89	0.89	0.15	0.02

Source: Author summarizes from the 2007 Household Socio-Economic Survey of Thailand

In conclusion, the SES survey results reveal that poor households are located in the north and northeast regions, mostly in non-municipal areas. Poor households engage mainly in agricultural and low-skill activities. Lots of poor households do not have members with a permanent job. Income of poor households comes from several sources, both from economic activities such as wages and salaries, and profits from business and farming, and from economically inactive sources such as assistance from persons outside the household or from the government. Regarding household expenditures, about half of their spending is on food consumption.

Chapter 4: Impacts of Trade Reform on Greenhouse Gas Emissions in Thailand

4.1 Introduction

Theoretically, international trade enlarges markets and enhances the efficiency of resource allocation, which in turn boosts economic growth. Other benefits, such as poverty reduction and improved income distribution, are also often experienced. To obtain benefits from trade, many countries, including Thailand, promote trade policies, particularly free trade, as instruments for boosting economic growth. However, at the start, the impact of international trade on social, environmental, and other issues was not much emphasized.

Global awareness of international trade and environmental concerns were starting to be of interest at the United Nations Stockholm Conference on Development in 1972 and the Earth Summit in 1992 (Jayadevappa & Chhatre, 2000). Concern on this topic increased rapidly in the 1990s. It was an important and widely discussed issue during the Uruguay Round of the GATT and the Doha Round of the WTO. International trade as come under scrutiny regarding its environmental impacts, particularly in developing countries. In the absence of solid environmental policies, trade can promote growth that is amenable to pollution-intensive industries that destroy local environments. This is a result of the relocation of pollution-intensive production from tightly regulated countries to countries with lax environmental regulations, so-called “pollution havens.” However, trade may lead developing countries to specialize in less pollution-intensive industries. Economic growth induced by trade increases real income and then shifts domestic production toward cleaner technology.

In addition, international trade changes domestic production structure. Since pollution emitted from each production sector is different, changing in the level of production leads to changes in the level of pollution. Thus, change in the share of pollution-intensive production in overall production is an important determinant of environmental impacts from international trade. The trade can be beneficial or harmful to the environment depending on how the production structure of a country changes after international trade is promoted.

The environmental impacts of trade reform can be defined in various ways depending on the available data and the researcher's interest. They can be considered as environmental degradation, such as pollution, or by examining related environmental problems like resource depletion and climate change. Climate change, measured by changes in the level of GHG emissions, has been addressed in several prior studies because of increasing awareness of global warming. The correlation between trade and climate change has been confirmed in many studies, including research conducted by the WTO & the UNDP (2009).

In this chapter, the impacts of trade reform on GHG emissions in Thailand, with a focus on carbon tax are examined. The simulation of an implementation of a carbon tax represents the case that Thailand places importance on GHG emissions. Trade reforms are proposed, as the import tariff is zero for all commodities. As in the dialogue in Chapter 2, so far Thailand is a country with a significant degree of openness, but it still lacks environmental regulations. Results are expected to contribute benefits both in terms of verifying the relationship between trade and GHG emissions and proposing appropriate trade and environmental policies for Thailand.

This chapter is organized as follows. Section 4.1 provides the background of this study. Section 4.2 reviews previous related studies. Section 4.3 explains the theoretical concepts. Section 4.4 shows the methodology used in this study. Section 4.5 presents the results of the model simulation. Section 4.6 summarizes and discusses simulation results. Section 4.7 explains conclusions and suggestions regarding the findings in this chapter.

4.2 Literature Review

As mentioned in the previous section, the environmental impacts of trade reform can be defined in several manners. One of them is climate change, which is indicated by GHG emissions. In this section, the previous literature on trade reform and the environment is discussed. Note that it is worthwhile to look at studies relating the impacts of trade on all aspects of the environment, not only on GHG emissions, since these are closely related theoretically.

Discussions on the impacts of trade on the environment have a long history, both theoretically and empirically. Many theoretical concepts have been proposed, but among of them, the most popular debates on this topic are based on the KLE theory and the PHH, which were mentioned earlier.

The link between environmental quality and trade was emphasized by Grossman and Krueger (1991)**,** who developed some useful knowledge about the impacts of trade on the environment. They divided the effects of freer trade on the environment into three main effects—the scale effect, the composition effect, and the technique effect—and tested them with available data. They found that the impact of trade on the environment is determined by the difference in factor abundance, as asserted in the KLE theory. Copeland and Taylor (1994) further developed the model, focusing on North-South trade. The results support Grossman and Krueger (1991). They found that the North (developed country) tended to specialize in cleaner goods after trade with the South (developing country). Antweiler et al. (2001) introduced a comprehensive model in which the three effects were clarified.

A growing number of empirical works is producing evidence that the impacts of international trade on the environment can be either positive or negative. For instance, trade is good for the environment of Latin America (Birdsall & Wheeler, 1993), whereas studies of China (J. M. Dean, 2002), Vietnam (Jha & Mani, 2006), and Nigeria (Feridun, Ayadi, & Balouga, 2006) have shown that there is a negative relationship between trade and the environment. Some previous studies are summarized and discussed below. Note that in the studies discussed below on the impacts of trade on the environment, trade has been defined in various ways, including tariff reduction or trade reform, trade liberalization, as well as level of exports or imports. Environmental impacts are frequently expressed in terms of pollution and GHG emissions.

A study that observed a positive relationship between trade and the environment was conducted by Birdsall and Wheeler (1993), who performed an empirical test using data from 25 countries in Latin America. Outcomes showed that trade improved environmental quality through income growth. They explained further that the improvement was also derived from environmental standards put in place by trade partners, specifically developed countries. A positive relationship between trade and the environment was also discovered in research conducted by Dean (2002). This study measured the impacts of trade on the environment using Chinese data for empirical analysis. Results revealed that China had comparative advantages in carbon-intensive goods. Thus, trade, from the perspective of the composition effect, is seen as detrimental to the environment. At the same time as trade increased income, it was expected to reduce GHG emissions. In total, the results showed that the adverse impacts on the environment were superseded by the positive effects on income growth. The study concluded that trade is good for the environment.

However, several studies show different findings and indicate that trade openness has negative impacts on local environmental quality. Yang (2001) studied the environmental consequences when Taiwan engaged in the WTO Agreement. The effects of trade reform, which are measured by a modification in production structures and a change in carbon emissions were examined using the CGE analysis. Carbon emissions were linked with coal, gas, and oil consumption. Results showed that when Taiwan engaged in trade reform, carbon emissions increased because of economic expansion. The production structure shifted towards carbon-intensive production. This study also measured the scale, composition, and technique effects using the Laspeyres index decomposition method. Results confirmed that an increase in carbon emissions is a result of the composition effect. Undesirable impacts on the local environment from international trade were confirmed in a study by Yunfeng and Laike (2010), who employed an input–output method to estimate the extent of carbon dioxide, a proxy of environmental impacts, embodied in China's imports and exports. The result showed that carbon emissions in export goods are higher than carbon emissions in import goods, which means that China’s trade was not positive for the environment. Carbon emissions embodied in trade were decomposed into the scale, composition, and technical effects. The authors observed that an increase of export goods is linked to negative impacts from the scale and composition effects. In other words, both effects caused China's total carbon emissions to increase. However, the technique effect contributed positive benefits to carbon emissions via emissions factor improvement.

Studies on other developing countries have supported the notion that freer trade should be implemented with environmental concerns in mind because it might damage the local environment. Jha and Mani (2006) examined the impacts of trade reform on the environment of Vietnam. Their findings revealed a positive relationship between trade reform and expansion of pollution-intensive industries. Alternatively speaking, they explored the composition effect of trade reform. Toxic pollution-intensive and water pollution-intensive exports expanded to a greater extent than less pollution-intensive sectors, but air pollution- intensive exports turned down. The authors also investigated whether foreign direct investment was more prevalent in toxic pollution-intensive sectors. Based on the results, the authors concluded that trade reform contributed negative impacts to Vietnam’s environment to some extent. Hence, environmental measures should be implemented. Feridun et al. (2006) calculated the scale, composition, and technique effects of trade reform on the environment using data from Nigeria. Results showed that the composition effect of Nigeria’s trade was negative. When trade was promoted, the production of pollution-intensive goods increased and had adverse effects on the environment. Although, income resulting from trade encourages local firms to introduce new environmentally friendly technology that offsets the negative impacts from the composition effect. The net impacts of trade reform are unfavorable on the environment. The author proposed that policymakers in Nigeria should place more concern on achieving freer trade and creating safety nets to protect the poor and the environment.

Trade may lead to negative environmental consequences in developed countries as well as in developing countries. It is worthwhile to note that trade need not worsen local environments directly, but can be an obstacle for the country to succeed in using environmental policy. Fæhn and Holmøy (2003) studied the impacts of multinational trade agreements, including the European Economic Area Agreement, the European Free Trade Association

Resolution on Fisheries, and the WTO Agreement on the environment of Norway, using intertemporal CGE analysis. Trade reforms, tariff reductions, and removal of non-tariff barriers under three agreements were considered. The environmental effects considered in this study were air emissions and solid waste. The study used various proxies to address air emissions, including GHG. The consequences of trade reform on the environment were considered via the scale and composition effects. Focusing on GHG emissions, the results showed that long-run emissions of GHGs increased by 0.4%, which destroyed Norway's potential to reduce GHG emissions under the Kyoto Protocol. However, the authors did not oppose trade reform, but advised policymakers to enforce extra policy to assure environmental protection.

Many of the studies discussed above examined the environmental impacts of trade and proposed that environmental protection policies should be enforced when trade openness is highlighted. The suggestion is logical, since there is a link between international trade, environmental regulation, and environmental impacts. Cole and Elliott (2003), by applying Antweiler et al.'s (2001) idea to analyze the composition effect of trade across countries, revealed that compositional change was determined by a country's environmental regulations, not by a country's endowments. Hence, imposing environmental policy was seen as important. Wilson, Tsunehiro, and Sewadeh (2002) examined the link between environmental regulations and pollution-intensive export expansion in 24 OECD countries and compared them with selected non-OECD countries. Their results confirmed the links between environmental regulations and export structure both in OECD countries and in non-OECD countries. Their study also found that environmental regulations are effective in some sectors but not all. In summary, the authors concluded that, in the context of international trade, implementing environmental regulations should be considered carefully.

The importance of environmental policy under free trade has been underlined by Beghin, Roland-Holst, and Van der Mensbrugghe (1997). Their study stressed the importance of environmental reforms after trade expansion. The idea has been supported by several empirical studies (see Al-Amin et al., 2008; Dessus & Bussolo, 1998; O'Ryan et al., 2005).

Limited empirical evidence is available for the study of the impacts of international trade on environmental quality in Thailand. Mukhopadhyay (2006) revealed that Thailand was a pollution haven. In his study, the trade structure when Thailand trades with OECD countries was analyzed; that is, the composition effect was evaluated. Findings indicated that Thailand increasingly exported pollution-intensive products and imported non-pollution-intensive products. Mukhopadhyay concluded that Thailand should consider its export structure and protect its environment by imposing stricter environmental regulations, enhancing technology, promoting clean technology to small and medium enterprises, and directing more concern to practical environmental standards. The negative impact of trade on the environment was also confirmed by Li (2005) who investigated the impacts of tariff reduction on the environment in Thailand. However, she found that the negative effects of trade on the environment were trivial. It was proposed that energy taxes together with tariff reductions be applied to protect the environment.

There is no common conclusion on the effects of trade on the environment in the previous literature. In many studies, findings on the impacts of trade on the environment differ from expectations based on the theoretical hypotheses. Environmental impacts also vary country by country. Therefore, this topic remains important and open to debate.

4.3 Theoretical Concepts

Theoretically, the impact of trade reform on the environment can be divided into three determinants; a scale effect, a technique effect, and a composition effect (Grossman & Krueger, 1991; Copeland & Taylor, 1994; J. M. Dean, 2002). The scale effect is measured as the increase in pollution that would be generated if an economic activity expands.[13] At the same time as

[13] Although the word pollution has been employed in theoretical discussions in previous studies, pollution has been defined broadly. In prior empirical research on this issue, pollution refers to various environmental degradation indicators such as air pollution, water pollution, solid waste, and greenhouse gas emissions.

economic growth increases real income, it brings about demands for a clean environment from consumers and encourages firms to shift towards cleaner production processes. This is referred to as the technique effect and usually contributes to positive benefits for environmental quality. The third effect, the composition effect, is a change in the production structure. Specifically, it is a change in the share of total production output of each sector. Since each production sector pollutes differently, changing the level of its production changes the level of pollution. In other words, the composition effect is a change in the share of pollution-intensive production in overall domestic production. The composition effect is emphasized as an important determinant of the relationship between international trade and the environment by many researchers. It can have advantageous or detrimental effects on the environment depending on how the production structure of a country changes after freer trade.

The composition effect involves the country's degree of openness and its comparative advantage (Managi, Hibiki, & Tsurumi, 2008). Comparative advantage can be determined by the difference in resource abundance (the capital-labor endowments [KLE]) or the asymmetry in the degree of environmental regulation (the pollution haven hypothesis, [PHH]). The KLE theory proposes that the comparative advantage of each country is different due to dissimilarities in resource endowment. A capital-abundant country will specialize in capital-intensive products while a labor-abundant country with will specialize in labor-intensive products. A capital-intensive industry is typically regarded as a pollution-intensive industry from the perspective of an environmentalist. Therefore, if the KLE theory is applied, it can be predicted that freer trade will induce a developed country (capital-abundant country) to specialize in pollution-intensive industries and will lead a developing country (labor-abundant country) to specialize in less pollution-intensive industries.

For the latter, the degree of environmental regulation is internalized in the cost of production (i.e., pollution abatement cost). Thus, a country with comparatively lax environmental standards has a comparative advantage in pollution-intensive industries, since lax environment regulations lead to lower costs of production compared with countries with strict environmental policies, *ceteris paribus* (Grossman & Krueger, 1991; Antweiler et al., 2001; Managi et al., 2008). With this knowledge, environmental regulation is important under free trade. Freer trade can harm the environment if there are no appropriate environmental policies in place.

Overall, the net of these effects may be positive or negative. The technique effect may offset the negative impacts from the scale effect, but the composition effect can contribute to either negative or positive effects and should be of concern to researchers and policymakers.

In this study, where climate change is taken into account, the adverse impacts of trade on the environment are measured by an increase in GHG emissions after trade reform. Regarding the conceptual discussion presented above, trade reform affects the level of GHG emissions in Thailand via three channels: the scale, composition, and technique effects. For the scale effect, trade reform stimulates economic activity through trade expansion, which consequently raises GHG emissions. At the same time, based on the technique effect, economic growth induced by trade expansion increases real income and the demand for environmentally friendly goods. A change in the share of carbon-intensive production in overall domestic production, the composition effect, could lead to an increase or a decrease in GHG emissions. If trade expands the carbon-intensive sector, GHG emissions will rise.

Recalling the simulation scenarios, to capture the impacts of trade reform on GHG emissions, which is the main objective of this study, two forms of trade reform are considered: full trade reform and partial trade reform scenario. In full trade reform, the import tariff is set to zero for all import goods.

4.4 Methodology

There are two steps in the analysis. In the first step, the CGE analysis discussed in the previous chapter is applied to simulate the macroeconomic impacts of trade reform and other policy scenarios. The detailed model and data used have already been described.

In the second step, results from the CGE analysis are used to calculate the environmental impacts, which are defined as levels of GHG emissions. Other types of pollution, such as soil degradation, land degradation, and wastewater, are not considered in this study due to data limitations. Levels of GHG emissions in all scenarios will be figured with respect to sectoral GHG emissions intensity conducted by Limmeechokchai and Suksuntornsiri (2007).[14] Based on the revised 1996 Intergovernmental Panel on Climate Change (IPCC) guidelines, three types of GHGs are selected to calculate GHG intensity: carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O).

To examine the environmental impacts of trade reform, the scale and the composition effects will be calculated using the method presented by Strutt and Anderson (2000). Unfortunately, due to the limited data, the technology effects associated with technology advancement will not be considered.[15] This study assumes that producers cannot upgrade their technology in the short term. Therefore, this study will modify the method of Strutt and Anderson (2000) to focus on the scale and composition effects. Total change in GHG emissions (*E*) is the sum of changes in emissions from each sector (E_j).

$$E = \sum_{j=1}^{36} E_j \tag{4-1}$$

where

$$E_j = S_j + C_j \tag{4-2}$$

j denotes the production sector in the model; and S_j and C_j represent the scale effects (*SE*) and the composition effects (*CE*), respectively. The total change in GHG emissions in each

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[14] GHG intensity is calculated for final consumption. See Limmeechokchai and Suksuntornsiri (2007).

[15] The "technology effect," defined in Strutt and Anderson's (2000) model, is closely related to the term "technique effect" mentioned in Grossman and Krueger (1991), Copeland and Taylor (1994), and Antweiler et al. (2001). The technology effect focuses on environmental improvement from the transfer of environmentally friendly technology after freer trade, while the technique effect emphasizes environmental improvement from rising demand for environmental standards as a result of an increase in income.

sector (E_j) is the sum of the scale and composition effects, which can be called "total effects" (TE). The scale and composition effects are calculated as follows:

$$S_j = \theta_j * g * X_j \tag{4-3}$$

$$C_j = \theta_j * (x_j - g) * X_j \tag{4-4}$$

The scale effect of sector j is computed by the product of the initial output level of sector j (X_j) and emissions intensity (θ_j) and the overall growth rate of real output (g). The scale effect indicates a change in emissions from a change in economic activity due to trade reform, with no concern for any transformation in production structure. The composition effect is computed by the product of the initial output level of sector j (X_j) and emissions intensity (θ_j) and the difference between the overall growth rate of real output (g) and the growth rate of output in each sector (x_j). The composition effect measures the effect from changes in production structure while maintaining the output level at the same level as before trade reform.

4.5 Results of the Study

This section discusses the results from the CGE simulation and the environmental analysis. Each sub-section explains the results from Scenario 1 to Scenario 6.

4.5.1 Impacts of Trade Reform (Scenario 1)

This section addresses the impacts of trade reform without the enforcement of any carbon tax. Before discussion about trade reform and GHG emissions, this study will explain the impacts of trade reform on the overall economy. It is important to discuss this topic even though GHG emissions and climate change issues are the main concentrations in this chapter, as changes in key economic indicators cannot be ignored. Policies that minimize GHG emissions but lead to economic contraction should be imposed carefully. Thus, to understand the impacts of trade reform thoroughly, macroeconomic impacts are addressed first.

The impacts of trade reform on the macro indicators are presented in Table 4-1. The CGE results show that trade reform generates an increase in exports, imports, and the GDP.

The GDP increases by 1.14% from the base level due to a large expansion in trade volume: 7.29% in exports and 7.82% in imports. The result follows basic international trade theory: when tariffs, a form of distortion, are removed, resource allocation will be more efficient. Welfare, measured by equivalent variation (EV), also increases.[16] However, net indirect tax declines by 36.11% because of tariff removal.

Table 4-1: Macroeconomic Impacts

	BASE (Bill. Baht)	S1 (%Ch.)	S2 (%Ch.)	S3 (%Ch.)	S4 (%Ch.)	S5 (%Ch.)	S6 (%Ch.)
GDP	9829.61	1.14	0.18	-0.05	-2.61	1.07	-1.73
Real GDP	9829.61	0.32	0.02	-0.10	-3.12	0.22	-2.86
Absorption	8643.02	0.67	0.10	-0.16	-3.76	0.48	-3.37
Private Con.	4998.14	0.67	0.02	-0.21	-7.15	0.48	-6.50
Fixed Inv.	2477.53	-0.67	-0.03	1.30	9.88	0.57	8.53
Gov. Con.	1167.35	3.46	0.73	-3.06	-18.17	0.32	-15.17
Exports	7132.30	7.29	1.62	0.11	3.06	7.40	10.31
Imports	-5945.71	7.82	1.79	-0.02	2.52	7.81	10.34
Net Ind. Tax	882.51	-36.11	-12.72	57.94	316.22	22.95	284.53
Price Index (DPI)	1.00	1.07	-0.16	0.31	5.05	1.34	5.92
EV		69.05	4.54	-25.85	-801.73	44.17	-741.20
Emission(MtCO_2e)	371.91	1.55	-0.72	-1.91	-12.50	-0.37	-11.09

Source: CGE Simulation Results

Tariff removal leads to changes in import prices. Import prices after trade reform are presented in APPENDIX B. The import prices in manufacturing n.e.c. sectors experience the largest decline, 32.04%. Import prices of beverage and tobacco, meat products, vegetables and fruit, transport equipment, and fishing drop by 27.02%, 16.24%, 12.07%, 11.49%, and 11.03%, respectively. Prices of other imported goods change within 10 percentage points. Changes in prices are as expected. Import prices in sectors with high tariffs decline greatly.

Modifications in import prices affect the level of imports across sectors, as presented in Appendix C. The level of imports in the agro-industry and the light manufacturing sectors

[16] A change in welfare is measured by a percentage change in equivalent variation from consumption value in the base case.

increases from 2.99% to 88.15%. For the heavy manufacturing, imports increase in almost all industries except metal products and livestock, where levels of imports decline slightly. Resource-based sectors, particularly the energy-related sector, do not benefit from trade reform because initial tariffs in these sectors are low.

According to the model structure, changes in the domestic prices of imported goods due to tariff reduction are related to the volume of domestic production. Specifically, changes in the relative prices of imported and domestically produced goods are linked with the composite prices of the goods. When import prices decrease (increase), demand for imported goods will increase (decrease) and demand for domestically produced goods will decrease (increase). Composite goods are distributed to households and government, investments, and producers (as intermediate inputs) associate with their demands. Considering the producers, changes in composite prices lead to changes in manufacturing production costs and, in turn, the level of production. It is important to note that a net change in a sector's production depends on changes in supply and demand. The changes in supply come from variations in production costs, as discussed above. The changes in demand involve substitutions between imported and domestically produced goods. A net change in the volume of domestic production is significant with regard to GHG emissions.

After trade reform, sectors can be "winners" or "losers." In this study, winners are defined as sectors with an increase in their production (or production expansion). Losers are sectors that contract after trade reform. The results of trade reform at the sectoral level are presented in Table 4.2.

The changes in domestic production shown in reveal that most of the winners are on the industrial side. Production in the food manufacturing, electronic equipment, and machinery sectors increases by 1.83%, 2.56%, and 1.70%, respectively. The transportation sector also expands by 2.02%.

Table 4-2: Sectoral Outputs

Sector	BASE (Bill. Baht)	S1 (%Ch.)	S2 (%Ch.)	S3 (%Ch.)	S4 (%Ch.)	S5 (%Ch.)	S6 (%Ch.)
Total	22727.57	0.04	0.07	-0.44	-3.42	-0.40	-3.32
Primary Agriculture							
Crops	333.09	-0.10	0.18	-0.01	0.47	-0.10	0.38
Vegetable and Fruit	372.89	0.15	0.07	0.06	0.14	0.21	0.29
Sugar cane	43.30	0.96	0.22	-0.39	-2.85	0.59	-1.81
Livestock	201.89	-0.36	-0.70	-0.07	-1.08	-0.43	-1.46
Resource-based							
Forestry	45.47	-2.21	0.03	0.84	4.81	-1.32	2.89
Fishing	177.41	-0.13	-0.28	-0.03	-0.47	-0.15	-0.57
Coal	21.76	-0.05	-0.04	-0.11	-2.42	-0.17	-2.60
Oil	194.32	-0.01	-0.03	0.15	1.14	0.13	1.06
Gas	69.97	0.01	-0.03	0.13	0.67	0.14	0.62
Mining	145.87	-0.06	-0.23	-0.22	-2.80	-0.29	-2.92
Agro-industry							
Meat Products	223.25	-0.73	-1.91	0.11	-0.10	-0.62	-0.81
Food Products	1091.63	1.83	0.40	-0.39	-2.31	1.48	-0.37
Dairy products	73.68	-2.89	0.25	-0.27	-3.48	-3.20	-6.71
Beverages and Tobacco	227.46	-6.68	0.23	0.43	0.01	-6.30	-6.81
Light Manufacturing							
Textile and Apparel	890.85	0.18	-1.03	-0.41	-4.78	-0.18	-4.43
Leather products	191.19	-0.32	1.26	1.04	7.74	0.84	8.38
Wood products	223.07	-0.38	0.46	1.72	11.55	1.38	11.32
Paper and publishing	262.07	-0.85	-1.54	-0.31	-2.87	-1.19	-4.09
Heavy Manufacturing							
Petroleum and coal	1127.90	-1.53	-0.18	-2.49	-15.21	-4.03	-16.65
Chemical, rubber, plastic	1661.95	0.47	-0.22	-0.39	-1.85	0.13	-1.13
Non-Metal Product	374.26	-2.23	-2.59	-5.06	-40.50	-7.52	-44.34
Metal Product	747.68	0.37	-0.05	-6.00	-42.53	-5.57	-41.74
Transport equipment	1429.49	-1.48	1.13	-0.13	0.94	-1.56	-0.13
Electronic equipment	1767.99	2.56	0.62	0.13	2.95	2.80	6.21
Machinery	1514.35	1.70	1.04	1.02	6.22	2.82	8.70
Manufacturing n.e.c.	445.47	-10.47	1.73	0.22	2.27	-10.42	-9.34
Utilities							
Electricity	464.42	0.04	-0.23	-2.60	-27.65	-2.52	-27.37
Gas manufac.	278.16	0.00	-0.21	-2.01	-21.93	-1.98	-21.75
Water	57.13	-0.06	-0.07	-0.28	-5.42	-0.34	-5.46
Transportation	1292.56	2.02	-0.19	-4.12	-22.33	-2.20	-20.81
Services							
Construction	860.59	0.24	0.13	-0.25	-1.78	0.00	-1.44

Sector	BASE (Bill. Baht)	S1 (%Ch.)	S2 (%Ch.)	S3 (%Ch.)	S4 (%Ch.)	S5 (%Ch.)	S6 (%Ch.)
Trade and Financial Service	3861.40	-0.16	-0.16	1.15	5.74	0.96	5.31
Communication	298.05	-0.21	-0.11	0.75	3.08	0.51	2.67
Recreation	429.83	0.55	0.12	0.32	-1.40	0.89	-0.83
Public Services	1182.93	-0.13	-0.07	0.60	3.06	0.46	2.81
Dwellings	144.26	-0.03	-0.01	0.04	0.16	0.02	0.12

Source: CGE Simulation Results

As previously mentioned, sector production decisions depend on production costs. Cost structures are presented in Appendix D. In Appendix D, a column refers to the total production costs of each sector in percentage terms. Total production costs come from the intermediate inputs from 36 production sectors, primary inputs and producer tax.

For example, an expansion in food manufacturing after trade reform comes from cost advantages. Considering cost structure and prices of input, intermediate input prices used in food manufacturing decline after trade reform. Main inputs used in food production are from the following sectors: dairy products (23.25%), food products (13.07%), and livestock (8.79%). The composite prices of goods for the above sector change by -3.12%, -3.24%, -1.90%, respectively. A drop in input prices generates an increase in production in this sector. An expansion of production indicates that cost advantages override the drop in demand from a rise in import goods.

For the losing sectors, domestic production in sectors that carried high tariffs before trade reform (such as beverage and tobacco, and manufacturing n.e.c.) declines, since those sectors lose trade protection. The results reveal that manufacturing n.e.c. contracts the most, with a decrease in production of 10.47%, followed by the beverage and tobacco sector, which suffers a local production decline of 6.68%. These results correspond with the changes in imports discussed above. Imports of beverage and tobacco as well as manufacturing n.e.c. increase significantly. Domestic production shrinks because of import substitution.

For environmental impacts, presented in Table 4-3, overall GHG emissions increase after trade reform (1.55%). The scale effect (SE) shows that the increase in GHG emissions deriving from economic expansion after trade equals 1.31%. The composition effect (CE) from the relative expansion of carbon intensive industries also yields a positive number (0.23%).[17] This result indicate that, after trade reform, GHG emissions rise from the expansion of carbon-intensive sectors. Roughly speaking, the production structure of Thailand after trade reform shifts towards carbon-intensive industries.

Note that the primary source of the increase in GHG emissions is the transportation sector (see Table 4-3). This finding is consistent with the report by the WTO and the UNDP (2009), which proposed that the transportation sector plays a crucial role in GHG emissions. The logic behind the relationship of trade reform, transportation, and GHG emissions is straightforward. Trade expansion from tariff cuts leads to an expansion of the economic activities and raise the demand for transportation. The transport sector is considered a carbon-intensive industry because its GHG emissions intensity is 100.21 tCO_2e/million Baht compared with an average emissions intensity for all sectors equal to 45.43 tCO_2e/million Baht. However, to receive the benefits from economic expansion, an increase in GHG emissions from an expansion of the transportation sector may be unavoidable.

4.5.2 Impact of Partial Trade Reform (Scenario 2)

The macroeconomic impacts of partial trade reform, 100% tariff withdrawal in carbon-intensive sectors only, show similar results to those in Scenario 1, but the size of the changes are smaller. The GDP increases by 0.18% from the base level. Exports and imports increase by 1.62% and 1.79%, respectively. The EV shows that welfare also increases. Government income from indirect tax declines 12.72%, which is not as much as the change in the case of full trade reform.

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[17] In this study, carbon intensive industry is defined as an industry with an emissions intensity that is higher than average. Carbon-intensive industries include fishing, mining, textile and apparel, paper and publishing, chemical, rubber and plastic, non-metal products, metal products, electricity, construction, and transportation.

After tariffs are removed, the prices of import goods in carbon-intensive sectors decline. For example, the import prices of goods in the fishing sector, non-metal manufacturing sector, and textile and apparel sector decrease by 14.32%, 11.10%, and 8.28%, respectively. With lower prices on import goods, there is an increase in the import of carbon-intensive goods as substitutions for domestically produced goods. Domestic production in all carbon-intensive sectors decreases. Production in the non-metal product sector declines the most, 2.59%, which is greater than in Scenario 1, where production declines by 2.23%. Under full trade reform (Scenario 1), some carbon-intensive sectors expand domestic production, for instance, domestic production in the textile and apparel sector and the metal products sector increase by 0.18% and 0.37%, respectively. With partial trade reform, in contrast, domestically produced textile and apparel products as well as metal products decline by 1.03% and 0.05%, respectively. For non-carbon-intensive sectors, domestic production in most sectors increases. In brief, it can be roughly stated that non-carbon-intensive sectors expand while carbon-intensive sectors shrink after trade reform.

Overall GHG emissions decline by 0.72%. The scale effect shows that the increase in GHG emissions from economic expansion after partial trade is 0.35%, as presented in Table 4-3. The composition effect from relative expansion of carbon-intensive industries shows a negative number (-1.07%). A negative composition effect implies that GHG emissions decline from the contraction of carbon-intensive industries. In other words, partial trade reform shifts the production structure of Thailand towards non-carbon-intensive industries.

Different from Scenario 1 (tariffs removed across the board), partial trade reform shows more success in GHG emissions control. This policy reveals that, to some extent, trade policy can be an instrument for reducing GHG emissions.

4.5.3 Impacts of Carbon Tax (Scenario 3 and 4)

This section discusses the results of Scenarios 3 and 4, which are carbon taxation without trade reform scenarios. In Scenario 3, a lax carbon tax equal to 500 Baht/tCO2e is imposed across sectors. This tax is collected with reference to the emissions intensity of each sector. Sectors that emit high levels of GHGs are required to pay a correspondingly high carbon tax. For example, carbon tax rates are equal to 14.42% for the electricity sector, 10.39% for the non-metal products sector, and 5.01% for the transportation sector.

When a lax carbon tax is applied (Scenario 3), the GDP decreases by a subtle amount from the baseline, -0.05%. Welfare also declines. However, implementation of the lax carbon tax raises government revenue, which largely comes from taxation. Government revenue from net indirect taxes increases by 57.94%.

These findings are predictable. A carbon tax is a distortion that increases production costs and causes economic contraction. At a sectoral level (Table 4-2), since the carbon tax rate is connected to levels of GHG emissions, sectors with high emissions are confronted with high tax rates compared to other sectors and, in turn, transfer their production costs, which finally results in a decline in production. For example, the transportation sector, and the metal and non-metal sectors contract by 4.12%, 6.00%, and 5.06%, respectively. Conversely, sectors with low GHG emissions, such as the forestry and service sectors, expand. These changes in sectoral outputs lead to a change in overall GHG emissions. In total, GHG emissions (Table 4-3) decrease 1.91% from the level at baseline. A reduction in GHG emissions is a result of both the scale effect and the composition effect. The scale effect is equal to -0.38%. The composition effect shows a contraction in carbon-intensive industries (CE = -2.91%) and an expansion in non-carbon-intensive industries (CE = 0.62%). Changes in the composition effect and the scale effect reveal that GHG emissions decline from both a contraction of carbon-intensive industries and a downturn in the overall economy.

Table 4-3: GHG Emissions

	Base	S1			S2			S3			S4			S5			S6		
	($MtCO_2$)	TE	SE	CE	TE	SE	CE	TE	SE	CE	TE	SE	CE	TE	SE	CE	TE	SE	CE
Total Economy	371.91	1.55	1.31	0.23	-0.72	0.35	-1.07	-1.91	-0.38	-1.52	-12.50	-3.80	-8.70	-0.37	0.93	-1.30	-11.09	-2.55	-8.54
Primary Agriculture	4.52	1.45	1.31	0.13	0.10	0.35	-0.26	-0.09	-0.38	0.30	-1.39	-3.80	2.41	1.35	0.93	0.42	-0.04	-2.55	2.52
Resource-Based	4.72	1.25	1.31	-0.06	-4.74	0.35	-5.09	0.26	-0.38	0.65	1.15	-3.80	4.95	1.50	0.93	0.58	2.27	-2.55	4.83
Agro-Industry	33.23	3.45	1.31	2.13	0.29	0.35	-0.07	-0.38	-0.38	0.00	-3.62	-3.80	0.18	3.07	0.93	2.14	-0.33	-2.55	2.22
Light Manufacturing	33.39	2.18	1.31	0.87	-3.35	0.35	-3.71	-0.18	-0.38	0.20	-3.51	-3.80	0.29	2.03	0.93	1.10	-1.30	-2.55	1.25
Heavy Manufacturing	131.58	2.31	1.31	0.99	-0.80	0.35	-1.16	-2.19	-0.38	-1.81	-14.58	-3.80	-10.78	0.11	0.93	-0.82	-12.49	-2.55	-9.93
Utilities	28.79	-0.84	1.31	-2.16	-0.27	0.35	-0.63	-4.81	-0.38	-4.43	-28.96	-3.80	-25.16	-5.55	0.93	-6.48	-29.18	-2.55	-26.63
Transportation	75.78	1.62	1.31	0.31	-0.25	0.35	-0.60	-4.01	-0.38	-3.63	-22.61	-3.80	-18.81	-2.48	0.93	-3.41	-21.40	-2.55	-18.84
Services	59.89	-0.44	1.31	-1.75	-0.18	0.35	-0.53	0.66	-0.38	1.04	0.89	-3.80	4.69	0.21	0.93	-0.72	0.38	-2.55	2.93
Carbon Intensive Sectors	226.20	1.67	1.31	0.36	-1.38	0.35	-1.73	-3.29	-0.38	-2.91	-20.52	-3.80	-16.72	-1.64	0.93	-2.57	-19.03	-2.55	-16.48
Non-Carbon Intensive Sectors	145.71	1.35	1.31	0.04	0.31	0.35	-0.05	0.24	-0.38	0.62	-0.06	-3.80	3.74	1.59	0.93	0.67	1.23	-2.55	3.78

Source: Author's calculation from CGE Simulation Results

In Scenario 4, a strict carbon tax, 2500 Baht/tCO_2e, is imposed in all sectors. From Table 4-1, it can be seen that the GDP drops significantly by 2.61%. Welfare shrinks about 6.68%. The strict carbon tax leads to noticeable economic contraction because it puts very high pressure on production costs. For sectoral impacts, as shown in Table 4-2, sectors with high carbon tax rates contract to a great extent. Domestic production of metal goods shrinks the most, -42.53%, followed by diminishing domestic production of non-metal products, which is equal to -40.50%. Production in other carbon-intensive manufacturing sectors also declines more or less. Production in the electricity sector and the transportation sector decreases by 27.65% and 22.33%, respectively.

Although the strict carbon tax has adverse impacts on economic growth and domestic production, it shows significant success in GHG emissions control. In this scenario, GHG emissions decline notably by 12.50% (Table 4-3), which is the greatest reduction among all the scenarios. This GHG reduction comes from a tightening in economic activity (scale effect), which leads to -3.80% in GHG emissions, and a decrease of GHG levels results in a contraction in carbon-intensive industry (composition effect), which is equal to an 8.70% reduction in GHG emissions. In summary, strict carbon tax succeeds in promoting non-carbon intensive sectors, although the economy will suffer a contraction.

A comparison between the simulation results for lax carbon tax (Scenario 3) and partial trade reform (Scenario 2) is useful. In terms of the size effect, both scenarios show a very small change in the GDP from baseline. In terms of GHG emissions, both scenarios are successful. The comparison is useful for policy implementation. If the policymakers wish to apply a policy to reduce GHG emissions, partial trade reform or lax carbon tax could be selected. Both policies cut GHG emissions without reducing economic growth.

4.5.4 Impacts of Trade Reform and Carbon Tax (Scenario 5 and 6)

These experiments aim to explore mixed policy between trade reform and the carbon tax. Scenario 5 and 6 examine impacts of trade reform on the GHG emission when the carbon tax is introduced. Scenario 5 is a combination of full trade reform (scenario 1) and lax carbon tax (scenario 3). Scenario 6 is a coordination of full trade reform (scenario 1) and strict carbon tax (scenario 4).

Starting with scenario 5, when lax carbon tax is applied together with full trade reform, macroeconomic index (Table 4-1) of this scenario shows similar effects to scenario 1. GDP increases by 1.07% that indicates benefits from tariff reduction dominate economic contraction caused by lax carbon tax. Trade volume expands, and welfare increases. However, production structure (Table 4-2) changes in a different way. For example, in contrast to scenario 1, the transportation sector cannot be considered as a "winner" in scenario 5.

As a result of production structure changes, GHG emission declines when the mixed policy of trade reform and lax carbon tax (scenario 5) is introduced. GHG emission declines by 0.37% compared to that in the baseline scenario (see Table 4-3). Scale effect is equal to 0.93% which represents GHG emission increased from economic expansion. Composition effect shows a tightening in the carbon intensive sector (CE equals to -2.57%) and an expansion in the non-carbon intensive sector (CE equals to 0.67%). Comparing with an increase in climate change risk from a rise of GHG emission in scenario 1, the results of scenario 5 show that such emissions can be reduced if the lax carbon tax is put in place.

An increase in GDP and a reduction in GHG emission as outcomes of the mixed policy of trade reform and lax carbon tax make the policy desirable. With this mixed policy, Thailand can enjoy benefits from trade without adverse impacts on climate change.

When strict carbon tax is introduced together with full trade reform (Scenario 6), the gain from trade is superseded by the contraction of the economy from strict environmental tax. As presented in Table 4-1, GDP drops by 1.73%. Welfare also decreases. For impacts on environment (Table 4-3), GHG emission significantly goes down (-11.09%). Both scale and composition effects show negative signs. Scale effect is equal to -2.55% showing the GHG emission reduction from economic shrinkage. Composition effect indicates a contraction of carbon intensive industry (CE equals to -16.48%) and an expansion in non-carbon intensive industry (CE equals to 3.48%). Changes of composition effect and scale effect expose that a decrease in overall GHG emission comes from economic contraction and a tightening of carbon intensive industries. Findings indicate that mixed policy of strict carbon tax and trade reform is effective for GHG mitigation but raises a question on its economic impact.

Simulation results of the two scenarios of the mixed policy of trade reform and carbon tax (scenario 5 and 6) not only highlight an importance of implementing policy as "package" but also address a significance of the degree of carbon tax as a determinant of the benefits from trade reform. For the first statement, a comparison of simulation results of full trade reform (scenario 1), the two scenarios of carbon tax (scenario 3 and 4), and the two scenarios of mixed policy (scenario 5 and 6) indicates that, if Thailand desires to utilize benefits from trade at the same time as saving environment from climate change, imposing policy package of full trade reform and lax carbon tax is required. For the second statement, comparing between two carbon taxes, the lax carbon tax is useful for protecting rising of GHG emission from trade reform with compromising benefits from economic expansion, but it seems not to be a solid measure for reducing GHG emission. In contrast, the strict carbon tax appears to be more appropriate in term of climate change protection, but its drawback on economic benefits should be noted.

It is important to note also that the degree of an initial tariff is important. If the initial tariff is small (country's trade policy is close to free trade), carbon tax plays a crucial role in changes in production structure, economic and environmental impacts.

4.6 Summary of the Results and Discussion

According to the theoretical concept, international trade brings about an expansion of the economy, in particular, economic growth. However, the country may have to accept an increase in GHG emissions at the same time. A summary of the relationship between the GDP (as a proxy of economic impact) and GHG emissions (as a proxy of effects on the environment effects) is shown in Table 4-4.

Table 4-4: Summary of GHG Emission and GDP under Different Policy Schemes

	Base	S1	S2	S3	S4	S5	S6
GDP (Billion Baht)	9829.61	9942.00	9847.39	9824.64	9572.94	9935.09	9659.30
(%Ch.)		(1.14)	(0.18)	-(0.05)	-(2.61)	(1.07)	-(1.73)
Real GDP (Billion Baht)	9829.61	9861.43	9831.81	9819.80	9523.27	9851.47	9549.01
(%Ch.)		(0.32)	(0.02)	-(0.10)	-(3.12)	(0.22)	-(2.86)
GHG Emission ($MtCO_2e$)	371.91	377.66	369.24	364.82	325.41	370.52	330.65
(%Ch.)		(1.55)	-(0.72)	-(1.91)	-(12.50)	-(0.37)	-(11.09)

Source: CGE Simulation Results

The results confirm that trade has an adverse effect on the environment. Thailand receives economic benefits from trade, but it has to accept the accompanying adverse environmental impacts from increased GHG emissions. When tariffs are removed across the board (full trade reform), GHG emissions increase from baseline (371.91 $MtCO_2e$) to 377.66 $MtCO_2e$. An increase in GHG emissions is an environmental cost of trade reform. However, when the tariffs are removed only in carbon-intensive industries (partial trade reform), GHG emissions decline from baseline to 369.24 $MtCO_2e$. This shows that partial trade reform can reduce the negative effects of free trade on the environment of Thailand.

When carbon tax, as a representative of environmental regulation, is put in place, the adverse impacts of trade on the environment are eliminated. In this study, an enforcement of Scenario 5 (a combination of full trade reform and lax carbon tax) and Scenario 6 (a combination of full trade reform and strict carbon tax) decreases GHG emissions in Thailand by 0.37% and 11.09%, respectively. However, with respect to economic growth, the policy of Scenario 5 is more desirable. It raises the GDP by 1.07% from baseline and reduces GHG emissions by 0.37% at the same time.

4.7 Conclusions and Policy Implications

This section concludes with the results of the study. There are six important issues that will be addressed.

First, for Thailand, trade reform itself is not good for the environment. Thailand gains benefits from an increase in the GDP but has to accept an increase in GHG emissions. Trade also shifts the economic structure towards carbon-intensive sectors. If Thailand would like to protect its environment from an increase of GHG emissions, partial trade reform should be considered instead of the full trade reform.

Second, if full trade reform is achieved without any complementary environmental protection measures, GHG emissions rise, which implies that Thailand could be confronted with climate risk at some point. Hence, environmental regulations should be concerned with protection against climate change. The findings from this study indicate that there is a policy that would allow Thailand to benefit from trade without incurring environmental damage. In this study, the combined policy of full trade reform and lax carbon tax leads to that goal. By introducing this policy, policymakers can ensure that Thailand can pursue development without adverse environmental impacts.

Third, the degree of environmental regulation should be emphasized. A mixed policy of trade reform and carbon tax should be implemented carefully. A carbon tax that is too strict could lead to economic contraction.

Fourth, if climate change is a central concern, policymakers should consider partial trade reform and a lax carbon tax as policy instruments to address this concern. These two policies may not confer much benefit on economic growth, but they are effective for dealing with rising GHG emissions. Thai policymakers can implement these two policies in order to control local GHG emissions without also increasing the burden on the economy.

Fifth, as the results show, trade reform can be an instrument for enhancing economic growth, which implies that if Thailand is obligated to apply a carbon tax in the future (for instance, environmental measures to reduce GHG emissions to reach the target of the UNFCCC), the country should enforce it together with a trade reform policy. The mixed policy of trade reform and carbon tax will be more beneficial to the economy than enforcing carbon tax alone.

Sixth, the results show that the transportation sector contributes most to GHG emissions after trade reform. However, transportation service is linked to other economic activities. Carbon taxation for this sector should be introduced with this in mind. Other climate change policies that do not obstruct its activity but can reduce GHG emissions, such as implementing clean technology, should be promoted.

Chapter 5: Impacts of Trade Reform and Carbon Tax on Poverty and Income Distribution

5.1 Introduction

This chapter discusses the impacts of trade reform and carbon tax on poverty and income distribution. According to simulation results in the previous section, trade reform contributes benefits to economic expansion. By merging full trade reform with a lax carbon tax (Scenario 5) or applying partial trade reform in the carbon-intensive sector only (Scenario 2), Thailand gains from economic expansion and lower GHG emissions.

Although both the partial trade reform policy and the mixed trade reform and carbon tax policy are beneficial for economic growth and the environment, there remain questions on their social impacts such as poverty and income distribution. For Thailand, as discussed in Chapter 2, poverty alleviation has been set as one of the goals of economic development since 1990s and is still a central dialogue in the Thailand National Development Plan. Not only poverty, but income distribution is also an important issue. Thailand has not successfully equalized income distribution. The Gini index, shown in Figure 2-9 in Chapter 2, indicates that there has been insignificant change for almost ten years. Based on the importance of poverty and income distribution issues, an appropriate policy package for Thailand cannot neglect either of them. Alternatively speaking, a policy that supports the environment but worsens poverty and income equality is undesirable. It raises unanswered questions on the mixed full trade reform and carbon tax policy as well as the full trade reform policy, which were proposed as appropriate policies in the previous chapter. For instance, "Are these policies suitable for Thailand if we consider the social impacts?" and "Is it possible for Thailand to gain from trade and benefits from GHG mitigation without increasing poverty?"

This chapter aims to assess the impacts of trade reform on poverty and income distribution in Thailand with regard to the role of carbon tax. The policy scenarios discussed in the previous section will be revisited with reference to poverty and income distribution.

This chapter is organized as follows. Section 5.1 introduces a statement of the problems and the research objectives of this chapter. Section 5.2 reviews related literature. Section 5.3 explains the conceptual framework. Section 5.4 expresses the methodology used in this study. Research findings are discussed in Sections 5.5 through 5.9 . Section 5.10 presents the conclusions and policy suggestions.

5.2 Literature Reviews

The main objective of this chapter is to determine the impacts of trade reform and carbon tax on poverty and income distribution. Previous studies regarding impacts of trade reform, carbon tax, and a mixed of the two policies on poverty are considered. There is a long tradition of research on the impacts of trade policy on poverty and income distribution (see Cockburn, 2002; Nahar, 2009; Naranpanawa, Bandara, & Selvanathan, 2011; Vos & De Jong, 2003). The impacts of carbon tax on poverty have also been investigated by several researchers, particularly with regard to sustainable development (see Dissou & Siddiqui, 2011, 2014; Yusuf, 2008). However, almost all of these studies focused on a single policy, either a trade policy or a carbon tax; only a few studies have focused on the impacts of a mixed trade reform and carbon tax policy on poverty.

In this section, studies regarding the impacts of trade reform, carbon tax, and a mixed policy of trade reform and carbon tax on poverty are discussed. First, prior studies that have focused on the impacts of trade reform on poverty are reviewed, followed by studies about the impacts of carbon tax on poverty. Last of all, research on the impacts of a mixed trade reform and carbon tax policy on poverty is reviewed.

There are numerous studies regarding the impacts of trade reform on income distribution and poverty, with both cross-country and single country analyses. The methods of these studies can be roughly separated into two groups: econometric analysis and general equilibrium analysis. However, most of the studies address similar questions: how does trade reform affect income distribution and poverty in each country? Generally speaking, they attempted to answer whether trade is good for the poor not only economically, but also socially. Although the questions are similar, the results of these studies are different and vary country by country. Some selected literature, concentrating on the general equilibrium analysis that is the analytical method used in this study, is discussed below.

Cockburn (2002) used the CGE microsimulation technique for estimating the impacts of trade reform on poverty in Nepal. Trade reform was described as tariff removal. He assumed that the government raised the consumption tax to compensate for revenue lost from tariff removal. The results suggested that, in general, freer trade positively affected income distribution in Nepal. Nevertheless, the benefits from trade were not equally allocated among all households and, in turn, rural poverty increased, while the poverty in urban areas decreased. Arbache and Carneiro (2003) evaluated the impacts of trade reform on poverty and income distribution in Brazil. The results indicated that trade reform decreased unemployment rates while increasing income for both unskilled and skilled of labor; however, these impacts were limited. At household level, benefits from trade contribute to high- and middle-income households in greater proportion than to low-income households. Chitiga, Kandiero, and Mabugu (2005) studied the impacts of free trade on poverty and income distribution in Zimbabwe. The results proposed that trade had little positive effects on income distribution. Both the Gini index and the Atkinson index slightly decreased after tariffs were removed and the analytical results showed that unskilled labor had more gains than skilled labor from free trade. Free trade contributed relatively more benefits to the poor. Chitiga et al. (2005) further proposed that the decrease in poverty in urban areas was proportionately higher than in rural areas. Instead of focusing on location, Herault's (2007) study of trade reform examined poverty and income distribution in South Africa, considering race. The results demonstrated that trade reform in South Africa was pro-poor. The incidence of poverty among Blacks, who account for more than 95% of all the poor, was reduced. This positive result may be due to the increase in employment opportunities after free trade was introduced. Nevertheless, with regard to income distribution, trade reform had limited effects on equality. Income inequality was reduced among low-income households, but income inequality between low-income and high-income households was not affected.

Roland-Holst (2004) applied a general equilibrium analysis to study poverty in Vietnam after WTO accession. An innovative idea of the study was the use of a multi-market approach, which was able to capture change in income distribution across regions through differing prices. This approach was constructed based on the knowledge that the rural areas face more barriers to market access and, in turn, confront distorted prices. Research findings supported that price dispersion was an important determinant of inequality in income distribution. As well, price dispersion was a key factor in increased poverty. The author concluded that trade openness has a positive effect on income distribution and poverty if it facilitates market access in rural areas and adjusts prices equally.

Unlike the poverty and trade policy issue, there are still not many empirical studies on the poverty impacts from carbon tax, but they are continuously increasing. One possible reason for the scarcity of research on this topic is that the principal target of a carbon tax is not poverty alleviation, but rather offsetting environmental degradation. However, as previously stated, an appropriate policy for a developing country should not ignore the poverty problem. Impacts on poverty from carbon tax should be considered.

Most of the previous literature regarding carbon tax and poverty has been done in developed countries, and results show that a carbon tax is a regressive tax; in other words, it is not good for the poor. Some examples are studies of Canada by Hamilton and Cameron (1994), Australia by Cornwell and Creedy (1996), Denmark by (Klinge Jacobsen, Birr-Pedersen, & Wier, 2003) and Sweden by Brännlund and Nordström (2004). A selection of studies will be discussed in this section.

Some empirical evidence reveals different outcome. Yusuf (2008) studied the impacts of carbon tax and energy pricing reform in Indonesia using the CGE model. This study examined the idea that the carbon tax is a regressive tax, as was claimed in many previous studies (see examples above). Yusuf attempted to prove that carbon tax is not necessarily regressive for developing countries. Research findings showed that, in Indonesia, a carbon tax was a progressive tax. He also analyzed rural and urban areas separately. The results showed that the carbon tax was strongly progressive in rural areas and either neutral or slightly progressive in urban areas. Therefore, a carbon tax was good for equalizing income distribution. Dissou and Siddiqui (2011) applied a multi-household general equilibrium model analysis to study the distributional impact of a carbon tax in Canada. Apart from the previous literature discussing income inequality on the expenditure side, this study measured post-policy results both in terms of change in income and the consumption side. Differently from previous studies, this study found a U-shaped relationship between income inequality and carbon tax, which means that the impact of a carbon tax changes from progressive to mildly regressive when the level of carbon tax increases. The authors claimed that household income is an important determinant of the relationship between carbon tax and income inequality and should not be ignored. Dissou and Siddiqui (2014) confirmed that a measure of the impacts of a carbon tax using only data for household expenditures is misleading and should be reconsidered.

For trade, the environment, and poverty issues, Corong (2008) used a CGE analysis to perform an economy-wide analysis of the impacts of tariff reduction and a carbon tax in the Philippines. The results showed that both tariff reduction and a joint policy of tariff reduction and carbon tax reduce poverty. However, the benefits of those policies are not equally distributed among workers. For instance, government workers received the largest increase in welfare, while agricultural workers and blue-collar industrial workers gained the least. Thus, tariff reduction and a mixed policy of tariff reduction and carbon tax were good for poverty, but not income distribution.

For Thailand, there is no previous literature that focuses directly on the impacts of trade policy and carbon tax on poverty. Wattanakuljarus and Wongsa (2011) assessed the impacts of a carbon tax on the Thai economy using a CGE analysis. The impact on poverty is somewhat addressed. They found that a carbon tax increases household income or decreases household income in the first and second decile, respectively, and increases the income of other household groups.

5.3 Theoretical Concepts

Trade reform impacts poverty and income distribution through changes in household income and expenditures. With regard to household expenditures, trade reform changes the price of the goods that households consume. If the prices of goods that are consumed by households decline, households experience benefits from trade reform, and vice versa. With regard to household incomes, sources of household income are wages and rent, which depend on the amount of labor and capital a household possesses. Thus, changes in wages and rent after trade reform affect household income. The Stolper-Samuelson theorem, which is derived from the Heckscher-Ohlin trade theory, is a famous theorem that discusses changes in wages and rent through trade.[18] The Stolper-Samuelson theorem proposed that, when a country liberalizes its trade, an increase in the price of a good tends to increase more than proportionally the price of the factor used intensively and to decrease the price of the other factors. Since developing countries are usually labor-intensive countries, labor tends to receive benefits rather than capital. In terms of labor, developing countries seem to have an abundance of unskilled labor and have a comparative advantage in the production of unskilled labor-intensive goods. Hence, freer trade enlarges the export sector of developing countries, which is unskilled labor-intensive. Consequently, unskilled labor gains from trade more than skilled labor. Since unskilled laborers are usually the poor, we can roughly infer that raising the income of unskilled labor through trade reduces poverty and improves income distribution by reducing the income gap between the rich and the poor.

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[18] The Heckscher-Ohlin trade theory proposes that comparative advantage of each country is different due to dissimilar in the resource endowment. The idea of comparative advantage is based on basic economic concept of opportunity cost, the country will have comparative advantage at producing goods that are intensive in the factors of production which is that country is relatively abundant.

Nevertheless, it is essential to note that the Stolper-Samuelson theorem is limited by various assumptions and may be violated in the real world. There are numerous many factors that affect the trade patterns and wage structures of each country. For instance, rapid technological progress from trade spillover may raise the demand for skilled labor while reducing the demand for unskilled labor, in which case, the real wages of unskilled laborers would decline. Another example of the Stolper-Samuelson theorem's limitations is a change in relative price. The theoretical proposition stated that international trade affects income distribution via a change in relative goods prices. If prices in the domestic market are highly distorted, a country may not have a comparative advantage in labor-intensive products, but its resources will be allocated to produce other goods that have higher prices. With so many limitations, the conclusion on the impacts of international trade on poverty and income distribution remains controversial.

For a relationship between the carbon tax and poverty, the intuition behind the relationship is from the Stolper-Samuelson theorem (Dissou & Siddiqui, 2014) as well. An increase in carbon tax on goods affects the supply of production, since increased carbon tax translates into marginal costs of production and, consequently, decreases the demand for factor inputs. Returns from factor inputs change accordingly. If a carbon-intensive product belongs to a capital-intensive industry, then an increase in the carbon tax decreases the relative price of labor.

5.4 Methodology

5.4.1 A CGE-Microsimulation Analysis

A CGE-Microsimulation analysis (top-down approach) is the main instrument of analysis in this section. The CGE model used for analysis is the standard CGE model presented in Chapter 3. The results from the CGE analysis will be recalculated with household-level data for the poverty analysis. The household data are from the 2005 Household Socio-Economics

Survey (SES), which are cross-sectional data collected by the Thailand National Statistical Office (NSO). The SES data were discussed in detail in Chapter 3.

Changes in household welfare after the introduction of trade reforms and carbon tax are calculated following the method proposed by Chen and Ravallion (2004) and Teguh (2010). This method can capture the impacts on both household revenue and household expenditures. A modification of household welfare is measured follows.

Change in welfare:

$$\Delta W_i = -\sum_{j=1}^{m} p_j \left(q_{ij} - s_{ij}\right) \frac{dp_j}{p_j} + \sum_{k=1}^{n} w_k L_k^s \frac{dw_k}{w_k} \tag{5-1}$$

where ΔW is the change in the welfare of a household *i*; q_{ij} - s_{ij} is the net consumption of a product *j* of a household *i*; p_j is the price of a product *j*; L_k^s is the household's labor and non-labor supply of activity *k*; w_k is the return on factors of activity *k*.

The change in household welfare is represented as a money metric. It is the sum of changes in household expenditures and revenue. The change in household expenditures is due to a change in the price of the composite goods that a household consumes. Note that, in this study, household consumption patterns are assumed to be unchanged after trade reform policy and carbon tax are implemented. The change in household revenue is derived from a change in the return on factors.

The change in household welfare is used to calculate new household income, which is represented by the expenditure function derived from indirect utility, as explained below.

$$E_i((p_{0j} + dp_j), (y_{0i} + \Delta W_i)) = E_i((p_{0j} + dp_j) + \Delta W_i \tag{5-2}$$

The new household's income is $E_i((p_{0j} + dp_j), (y_{0i} + \Delta W_i))$. This is equivalent to the initial household income in the SES database, adjusted by the change in household welfare (ΔW) calculated above. Since each household has a different consumption pattern and source of revenue, income is affected unequally. New household income is utilized for poverty analysis.

5.4.2 The Poverty Analysis

In this study, poverty is measured by the Foster-Greer-Thorbecke (FGT) index. The general formula of the FGT index is

$$P_\alpha = \frac{1}{n}\sum_{i=1}^{q}\left[\frac{z - y_i}{z}\right]^\alpha \qquad (5\text{-}3)$$

where P_α is the poverty index; z is the poverty line; y_i is the income (or expenditure) of a household i; q is the number of households below or at the poverty line; n is population size; and α is a sensitivity parameter.

If $\alpha = 0$, P_0 = Headcount Index

If $\alpha = 1$, P_1 = Poverty Gap

If $\alpha = 2$, P_2 = Poverty Severity

The poverty line applied for poverty analysis in this study is equal to 2006 Baht per month. This poverty threshold refers to an official poverty line for the year 2007, proposed by the National Economic and Social Development Board of Thailand. In this study, a poverty line calculated based on the consumption side is employed, since consumption pattern is more robust than income.

The headcount index is the share of households with income below the poverty line. In other words, the household cannot afford to buy a sufficient quantity of goods. The poverty gap indicates how far the poor are from the poverty line. This signifies the minimum amount of money needed to bring the poor out of poverty. The severity of poverty gives a higher weight to households further away from the poverty line. It also signifies the level of income inequality among the poor.

In order to give a clearer picture of poverty impacts, relative poverty as income distribution will be considered too. Income distribution is measured by the Gini coefficient. The Gini coefficient measures the extent to which the distribution of income among households deviates from a perfectly equal distribution. A Gini coefficient is a number between zero and one. An index of zero corresponds to perfect equality, while an index of one means perfect inequality.

5.5 Results of the Study

This section presents the outcomes of an analysis of the impacts of trade reform and carbon tax on poverty and income distribution. Table 5-1 shows the incidence of poverty due to trade reform and carbon tax. A discussion of the results for each of the six previously analyzed scenarios is presented in the subsections.

5.5.1 Impacts of Full Trade Reform (Scenario 1)

First, the simulation results of changes in wage and returns on factor inputs after trade reform are discussed. The results are introduced in Appendix E to Appendix I. Full trade reform raises wages for all types of labor. Labor wages increase by 0.10% - 5.28% across labor types. For non-labor factor inputs, factor returns on land and agricultural capital rise in the sugar cane sector (9.76%) and the vegetable and fruit sector (1.56%), while they drop in the crops (-0.83%) and livestock (-3.21 %) sectors. Returns on natural resources increase by 0.33% - 5.56%, except in the forestry sectors, where returns decline by 15.39%. For non-agricultural capital, the simulation results show higher rents in the light manufacturing sectors (2.83% - 5.63%), and the utilities (5.09% - 8.22%) and service sectors (1.93% - 6.20%). Rents of most industries in resource-based, agro-industry, and heavy manufacturing sectors increase, except in the dairy products, beverage and tobacco, non-metal products, and manufacturing n.e.c. sectors. The findings are not consistent with the Stolper-Samuelson hypothesis, which anticipates that unskilled labor will receive the most benefits from free trade. Therefore, it cannot be simply inferred from the CGE analysis that the poor enjoy gains from trade reform and carbon tax policies. A microsimulation analysis is then utilized. The microsimulation results are explained below.

A poverty analysis is shown in Table 5-1. The results indicate that trade reform decreases poverty. The headcount index declines by 15.80%. The poverty gap drops by 16.58%. The severity of poverty decreases by 16.52%.

Table 5-1: Poverty Incidence

	Base	S1	S2	S3	S4	S5	S6
Headcount Index	0.161	0.136	0.135	0.148	0.255	0.144	0.243
		-(15.80)	-(16.22)	-(8.17)	(57.75)	-(10.86)	(50.63)
Poverty Gap	0.038	0.032	0.032	0.036	0.106	0.034	0.092
		-(16.58)	-(17.75)	-(7.09)	(176.39)	-(11.10)	(140.60)
Severity of Poverty	0.014	0.011	0.011	0.016	0.779	0.012	0.524
		-(16.52)	-(18.20)	(14.11)	(5595.25)	-(11.04)	(3733.55)
Gini Index	0.434	0.464	0.461	0.459	0.482	0.461	0.475
		(6.80)	(6.12)	(5.64)	(10.95)	(6.14)	(9.42)

Source: Author calculation
Note: Figures in parentheses indicate percentage change

A decrease in the headcount index implies a reduction in the number of households that have an income below the poverty line. According to the microsimulation procedure, household income changes because of an alteration in factor wages and goods prices. The characteristics of household incomes and expenditures are revealed in Appendix J to Appendix N. Household incomes are classified into five groups, from the first quintile to the fifth quintile. The first quintile, representing the poorest 20% of households, is the focus, as household incomes in this group are below the poverty line. Changes in the incomes of first quintile households will contribute to changes in overall incidence of poverty.

Revenues of a first quintile household are mainly from social safety nets such as pensions or welfare payments, followed by revenues from engaging in agriculture activity and unskilled labor working in non-agricultural businesses. For expenditures, the first quintile household spends on food products, grain and cereal products, and lodging, for the most part.

Considering changes in factor incomes (Appendix E to Appendix I), full trade reform increases returns from all factor inputs. For household revenue, households gain from changes in returns on factors. Though revenues for first quintile households decline from reduced returns from agriculture (-0.83%), those households enjoy an advantage from the higher wages for unskilled labor (5.18%). Revenue from other sources is assumed to be fixed. Since revenue from other sources is the largest source of revenue for first quintile households, household revenues do not change considerably. Considering changes in goods prices (Appendix O), composite prices in the housing sector increase, while the prices of food products as well as grains and cereal products drop. Thus, it can be expected that poor households that devote the largest part of their income to food will benefit from lower food prices.

Overall, net changes in welfare increase and household incomes increase accordingly. The headcount index decreases along with the reductions in the poverty gap and poverty severity.

For income distribution, results show that income inequality increases after full trade reform. The Gini index rises by 6.8%. The Gini index represents how income is distributed among households. An increase in the Gini index indicates that income is unevenly distributed. A decrease in the headcount index after full trade reform reveals an increase in the numbers of first quintile households with incomes that change upward towards the poverty line. It implies that incomes of other quintile households increase to a greater extent.

For example, fifth quintile households, which represent the richest 20% of households, spend a large share of income on transportation equipment, lodgings, and non-consumption (such as insurance premiums, donations, etc.). Under trade reform, though the composite prices of lodging increase by 1.64%, the price of transportation equipment drops by 7.56%. Non-consumption expenditures are assumed to be the same as prior to trade reform. Thus, in term of consumption side, the fifth quintile households seen to be better off after full trade reform from lower goods prices. For household revenues, primary sources of revenue in fifth quintile households are skilled labor and industry. Returns on skilled labor increase by 5.28% after full trade reform. The main industries that fifth quintile households belong to are in the trade and financial services sector, where the factor return rises by 55.75%. Therefore, in term of revenue side, the fifth quintile households gain benefits from higher returns of factor input. A vast improvement in household revenue and a reduction in the price of goods leads to a significant increase in household income. The increase in household income in the fifth quintile household is proportionally greater than the increase in household income in the first quintile. Consequently, income distribution after trade reform is degraded.

In summary, full trade reform is beneficial for poverty reduction but unhelpful for income distribution in Thailand.

5.5.2 Impacts of Partial Trade Reform (Scenario 2)

Partial trade reform increases the wages of all types of labor, although the size of the changes vary. The wages for labor increase by a range of 0.82% to 1.59%. For non-labor factors, returns to land and agricultural capital go up in all sectors except livestock. Rents for non-agricultural capital rise in most sectors, excluding fishing, mining, meat products, textile and apparel, paper and publishing, as well as non-metal product manufacturing. For the prices of goods, the composite prices increase from 0.01% to 1.03% in 25 sectors, while the prices of goods for the rest of sectors fall, for example, the meat products (-2.38%), textile and apparel (-4.22%), and chemical, rubber, plastic (-6.14%) sectors.

A net change in the prices of goods and the returns of factor inputs leads to a reduction in poverty. The headcount index drops by 16.22%. The poverty gap decreases by 17.75%. The severity of poverty declines by 18.20%. Therefore, partial trade reform is good for poverty reduction. However, the Gini index increases by 6.12%, which means income distribution is worsened when partial trade reform is implemented.

The decline in poverty after implementing partial trade reform is mainly from the increase in returns on factor inputs. An increase of 1.59% in the wages of unskilled labor raises the revenues of first quintile households. Partial trade reform also improves returns on agricultural capital, particularly the cultivation of crops, which is the second source of revenue for first quintile households, by 3.13%. An increase in household revenues after partial trade reform dominates an increase of expenditures from the higher prices of goods because the prices of goods that first quintile households consume changes slightly. For example, the prices of food products, dwellings, and crops, which represent a large share of first quintile household expenditures, increase by 0.46%, 0.16%, and 0.84%, respectively.

A worsened income distribution indicates that benefits from partial trade reform contribute to households asymmetrically. Findings show that gains from higher factor returns seem to be equally distributed across household groups. However, since the prices of goods increase in almost all sectors, fourth and fifth quintile households, which devote a large share of their total expenditures to non-consumption goods that do not experience price changes after partial trade reform, are less adversely affected than other household groups. As a consequence, fourth and fifth quintile household incomes increase proportionally more than first quintile household incomes.

Comparing the incidence of poverty under partial trade reform (Scenario 2) to full trade reform (Scenario 1), partial trade reform shows similar results in terms of poverty and income distribution impacts. Both full trade reform and partial trade reform are good for poverty reduction but undesirable for income distribution. Therefore, these two policies should be considered carefully if the policymakers are concerned with income inequality issues.

5.5.3 Impacts of Carbon Tax (Scenarios 3 and 4)

In Scenario 3, a lax carbon tax decreases wages across types of labor. Wages decrease from 1.39% to 6.36% as a result of the lower demand for labor because of shrinking domestic production. Labor in non-agricultural sectors encounters more negative effects from wage decreases than labor in agricultural sectors. Returns on land and natural resource use also fall off. For non-labor capital, rents fall in all sectors by 1.37% to 19.55%, excluding the forestry sector, where rents rise by 2.08%. Rents drop greatly in sectors with high carbon tax rates. For example, rents of capital in non-metal products go down by 19.55% since this sector faces a high carbon tax rate (10.39%). Note that the carbon tax increases the relative price of labor, as expected in the conceptual discussion. For the price of goods, prices slightly increase in a range of 0.04% to 3.65%, except electricity and non-metal goods, which experience price increases of 11.81% and 7.25%, respectively.

A net change in the price of goods and returns from factors brings about an adjustment to poverty. On the expenditure side, considering goods that poor households mainly consumes, the price of food products and crops slightly increase by 0.85% and 0.19% respectively, but prices in the housing sector decline by 0.16%. On the revenue side, since revenues in first quintile households are mainly from agents that are not affected by lower wages and rents, it can be inferred that revenues for the first quintile household do not change much. The benefit on the expenditure side from lower goods prices equalizes the loss of revenue from lower wages and, consequently, reduces poverty. The headcount index declines by 8.17%. The poverty gap drops by 7.09%, but the severity of poverty increases by 14.11%. An increase in the severity of poverty implies that there is an increase in income inequality among the poor.

The Gini index increases by 5.64%, which means income distribution is worse after an implementation of the carbon tax. In other words, household incomes are unevenly affected. An increase in the Gini index conforms to an upturn in the severity of the poverty index, which indicates a rise in income inequality among poor households.

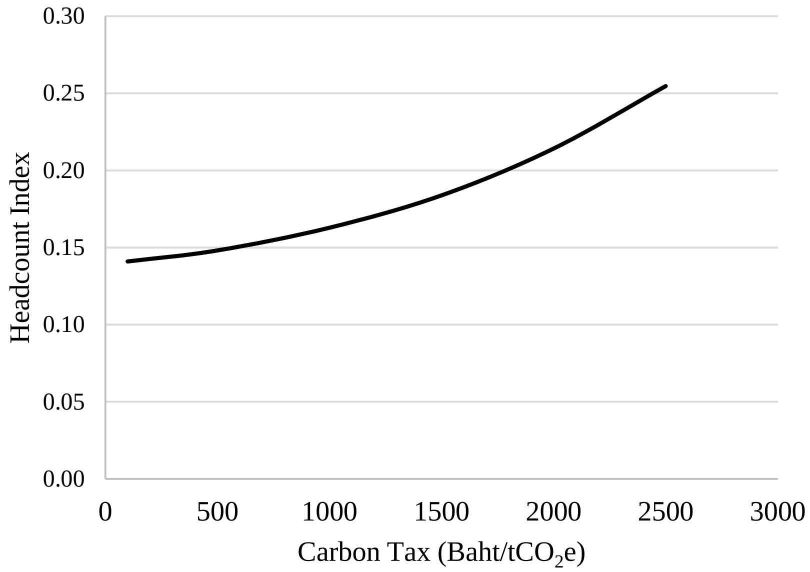
Note that, as discussed in the previous chapter, partial trade reform policy and lax carbon tax can be comparable in terms of their size effects on economic growth and efficiency with regard to reducing GHG emissions. In this section, the two policies are compared with reference to poverty and income distribution. Results show that partial trade reform is preferable for poverty reduction, while a lax carbon tax causes smaller negative impacts for income distribution.

For the strict carbon tax, Scenario 4, labor wages significantly shrink in all labor categories. Non-agricultural labor wages decline in a range of 34.22% to 36.10%, and agricultural labor wages range from 11.82% to 16.50% lower. For non-labor factors, returns on non-labor factors decrease in the same direction as in Scenario 3, but the proportions of change are larger. As well, the prices of goods move as in Scenario 3, but the changes are larger. For example, the price of food products increases 0.85% in Scenario 3, but increases 4.95% in Scenario 4. Straightforwardly, increasing goods prices and decreasing returns on factors lead to an increase in poverty. The headcount index increases by 57.75%. The poverty gap and the severity of poverty increase by 176.39% and 5595.25%, respectively. The Gini coefficient increases 10.95%, which demonstrates that inequality increases when a strict carbon tax takes effect. An increase in inequality reveals an asymmetrical alteration of household incomes. For instance, in a comparison between first and fifth quintile household incomes, although both groups of households encounter lower revenues from a reduction of returns on factors, the first quintile household has to bear greater expenses from higher goods prices that are mainly consumed. For example, while the price of food products, which represent about 18.11% of total expenditures, increases by 4.95%, fifth quintile households are less affected by these higher prices because they spend more on non-consumption goods, which have fixed prices.

In summary, with regard to poverty and income distribution, the lax carbon tax seems to be preferable. Although it slightly increases income inequality, the reduced poverty incidence reveals its positive impacts. The strict carbon tax, conversely, has negative impacts on both poverty and income distribution.

As the impacts of the lax carbon tax and the strict carbon tax on income distribution and poverty are dissimilar, it is useful to perform additional simulations regarding the relationship between the carbon tax and poverty (as well as income inequality) under different degrees of carbon taxation. Four simulations of carbon tax, 100 Baht/tCO2e, 1000 Baht/tCO2e, 1500 Baht/tCO2e, and 2000 Baht/tCO2e, are added. These simulation results, the relationship between carbon tax and poverty, are shown in Figure 5-1.

Figure 5-1: Relationship between Carbon Tax and Poverty



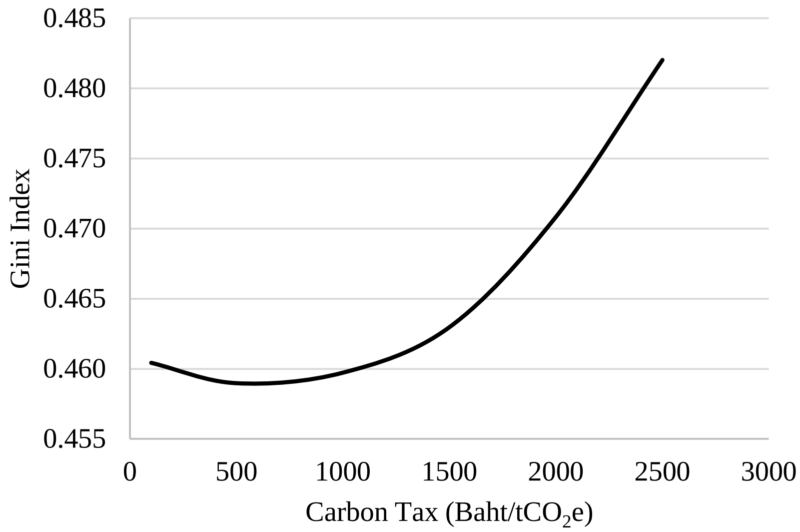
Source: Simulation Results

Without the carbon tax, the headcount index is equal to 0.16. The simulation shows that the headcount index declines to 0.14 when a 100 Baht/tCO2e carbon tax is applied. The headcount index increases when the degree of carbon tax becomes greater. Roughly speaking, at a low level of carbon tax, the carbon tax is good for the poor. However, when the level of carbon tax goes up, the headcount index increases, which means that carbon tax increases the number of poor households. Appendix P shows the average of the percentage change in household income classified by quintile group. Carbon tax at 100 Baht/tCO2e, 500 Baht/tCO2e, and 1000 Baht/tCO2e contribute positive changes to first quintile household income, but carbon tax at 1500 Baht/tCO2e, 2000 Baht/tCO2e, and 2500 Baht/tCO2e cause negative effects on first quintile household incomes. It can be inferred that at the low level of carbon tax, households gain benefits from an increase in revenues more than they suffer from the increase in commodity prices. However, when the level of carbon tax rises, wages and rents significantly fall and adverse impacts dominate the benefits, if any, of price reductions.

Figure 5-2 illustrates the relation between the carbon tax and inequality. As in the prior discussion, carbon tax legislation leads to an increase in poverty. The Gini index rises from 0.43

to 0.46 when a 100 Baht/tCO_2e carbon tax is imposed. However, the Gini index declines slightly with carbon taxes of 500 Baht/tCO_2e and 1000 Baht/tCO_2e. Appendix P shows that at a 100 Baht/tCO_2e tax rate, there are significant differences in changes in income between household quintile groups. At 500 Baht/tCO_2e and 1000 Baht/tCO_2e carbon tax, although fifth quintile households receive greater gains than other groups, the changes of income in all quintile households are not noticeably different. At a 1500 Baht/tCO_2e carbon tax, the Gini index increases again, which means that income inequality also increases. A U-shaped relationship indicates the importance of the degree of the carbon tax on income distribution. This result is similar to Dissou and Siddiqui's (2014) findings that carbon tax can be good for inequality at a low tax rate and bad for inequality at a high tax rate.

Figure 5-2: Relationship between Carbon Tax and Inequality



Source: Simulation Results

5.5.4 Impacts of Trade Reform and Carbon Tax (Scenarios 5 and 6)

In Scenario 5, trade reform is combined with a lax carbon tax. This scenario shows a small reduction in wages across types of labor. Labor wages decrease by 0.61% to 1.34%. For non-labor factors, returns of land and agricultural capital change differently across sectors. Land and agricultural capital obtain higher rents in crops and livestock but lower rents in other agricultural sectors. Returns on natural resource factors drop in forestry, fishing, coal, and mining sectors, but rise in oil and gas sectors. For capital in the non-agricultural sector, changes in rents are varied and range from -22.71% to 7.29%. The modifications to returns on factors discussed above are influenced by both trade reform and carbon tax.

Regarding the price of goods, the price of electricity shows the greatest increase, 16.16%, while the composite prices in the manufacturing n.e.c. sector have the lowest reduction, 21.12%. The prices of food products and crops decrease by 2.48% and 1.69%, respectively. The prices of goods and services in the housing sector rise by 0.85%. These three sectors affect changes in household expenses because they contribute greatly to the total consumption expenditures of first quintile households.

Lower prices on goods that first quintile households consume contribute to poverty reduction. Though wages and rental incomes decline, revenues of the first quintile household are not affected much because the largest source of total revenue comes from other sources. The headcount index declines by 10.86%. The poverty gap and the severity of poverty decline by 11.10% and 11.04%, respectively. A decrease in poverty shows that the mixed policy of trade reform and lax carbon tax is advantageous for poverty reduction. However, the Gini index increases by 6.14%, indicating that this policy does not promote redistribution of income.

To clarify the change in inequality, a modification of revenue and expenditures among household groups after implementing the mixed policy is discussed. The first quintile households obtain benefits from reduced goods prices, but they have to accept lower revenues. The fifth quintile households may not benefit from lower goods prices like the first quintile households, since they largely consume non-consumption goods with fixed prices, but they can receive revenue advantages. The wages of non-agricultural skilled labor, which is the primary source of fifth quintile household revenue, decreases only 0.61%, but rents from industry, which is another main source of their revenue, increase. Rents from trade, financial services, and recreation activities that account for more than 60% of their income from industry increase by 1.45% and 0.45% correspondingly. With the advantage of increased returns on factors, income in the fifth quintile household group possibly increases proportionally more than income in the first quintile household group, which, in turn, increases inequality.

Scenario 6 yields similar outcomes to Scenario 4. Since the carbon tax rate is very high, it negatively affects poverty and income distribution. Although the carbon tax is combined with trade reform, negative effects from the strict carbon tax dominate profit from trade reform. Labor wages drop considerably across all labor groups. Non-agricultural unskilled labor wages decline the most, by 31.77%. Agricultural labor wages drop by a range of 11.40% to 15.33%. Decreases in returns to non-labor factors are similar to the changes in Scenario 4, both in terms of direction and size. The prices of goods change as in Scenario 4 as well, but the magnitude of the change is somewhat dissimilar. Considering the three main sectors that contribute to first quintile household consumption, the prices of housing and crops decline by -15.29% and -2.34%, respectively, while the price of food increases by 1.05%.

A great drop in rents and wages, particularly the wages of non-agricultural unskilled labor, which is one of the main sources of first quintile household revenues, dominates gains from reduced prices on goods. The incidence of poverty increases. The headcount index goes up by 50.63%. The poverty gap and the severity of poverty rise by 140.60% and 3733.55%, respectively. The Gini index increases by 9.42%, indicating that inequality increases after the mixed policy of trade reform and strict carbon tax comes into force. The change in the Gini index can be explained as follows. Both first and fifth quintile households have to accept lower revenues from reduced returns on factors, but the first quintile households also have to accept higher expenditures due to their consumption patterns. The first quintile household consumes food products as the largest share of total consumption. The price of food products increases and, in turn, requires the first quintile household to spend more to attain the same consumption basket. For fifth quintile households, most of their expenditures are on non-consumption goods, transportation equipment, and housing. The price of non-consumption goods does not change and the prices of transportation equipment and housing drop between 4.96% and 15.29% respectively. With a reduction in those prices, the fifth quintile household seems to benefit from price changes more than the first quintile household. Accordingly, incomes in fifth quintile households do not fall as much as incomes in first quintile households and, thus, inequality among household incomes increases.

Compared with the single carbon tax policy in Scenarios 3 and 4, these two scenarios for a mixed policy of trade reform and carbon tax have fewer undesirable impacts on the poor, which are outweighed by the overall benefits from trade. The increase in inequality is smaller as well. Therefore, it can be concluded that, with regard to poverty, the mixed policy of trade reform and carbon tax is better than carbon tax alone.

5.6 Decomposition of Poverty

In order to gain a clearer understanding of the impacts of trade reform and carbon tax on poverty, this study applied the decomposition method following Datt and Ravallion (1992), which assesses the relative contributions of economic growth and redistribution to changes in poverty. The study points out that the decomposition of changes in poverty between two periods can be written as the sum of a growth component and a redistribution component and residual or error term.[19] The growth component is defined as a change in poverty assigned from a change in mean income while holding the Lorenz curve constant. The redistribution component is computed as the change in poverty due to a change in the Lorenz curve while keeping the mean income constant. The "residual" is the interaction term that represents the effect of simultaneous changes in mean income and distribution on poverty that cannot be captured by the growth and redistribution components.

Trade reform (both full trade reform and partial trade reform) results show that if there is no change in inequality, poverty falls by 6.04% (Scenario 1) and 5.63% (Scenario 2). However, increases in the redistribution component, which are equivalent to 3.95% (Scenario 1) and 3.24% (Scenario 2), offset gains from growth in reducing poverty.

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[19] In this study, this concept is applied for analyzing change between pre- and post-simulation.

Table 5-2: Decomposition of the Poverty

	Poverty Incidence (Headcount Index)	Change of Poverty	Growth Component	Redistribution Component	Residual
Base	0.161				
S1	0.136	-2.55	-6.04	3.95	-0.46
S2	0.135	-2.62	-5.63	3.24	-0.23
S3	0.148	-1.32	-3.78	2.75	-0.28
S4	0.255	9.32	7.48	1.76	0.09
S5	0.144	-1.75	-4.78	3.32	-0.30
S6	0.243	8.17	5.96	1.94	0.26

Source: Author's calculation

Lax carbon tax (Scenario 3) results indicate that if there is no change in inequality, poverty decreases by 3.78%, but an increase in the redistribution component that is equal to 2.75% diminishes the gains from growth in reducing poverty. Results reveal that a growth component dominates a redistribution component and, accordingly, poverty declines. The mix of trade reform policy and lax carbon tax (Scenario 5) shows that if there is no change in inequality, poverty declines by 4.78%. An increase in a redistribution component equal to 3.32%, however, decreases gains from growth in reducing poverty. It can be seen from the results that full trade reform is suitable for poverty alleviation (the growth component is equal to -6.04%); thus, it contributes positive impacts on poverty when it is combined with the lax carbon tax. However, since trade reform brings about inequality (the redistribution component is equal to 3.95%), it reinforces inequality from the lax carbon tax and increases the negative impact on income distribution when using a combined policy.

For strict carbon tax, if there is no change in inequality, poverty will increase by 7.48%. Change in inequality aggravates poverty; the redistribution component is equal to 1.75%, which means worse income distribution, which causes an increase in poverty by 9.32%. Decomposition of the mixed policy of trade reform and strict carbon tax gives results similar to the findings for strict carbon tax, but the results are lower. If there is no variation in inequality, poverty will increase by 5.96%. An increase in the redistribution component that is equal to 1.94% increases poverty. The total change in poverty is equal to 8.17%.

The decomposition of poverty confirms that all policy scenarios in this study have adverse effects on income distribution. They may have advantages for the economy, poverty, and the environment, but they do not succeed in redistributing income. Thus, those policies should be imposed carefully if the income distribution issue is a concern of the policymakers. Other supplementary policies dealing with income distribution should be applied.

5.7 Dynamics of Poverty

In this section, changes in the poverty status of households before and after the simulation are presented in Table 5-3. Poor households are represented with P, and NP refers to the non-poor households. Before trade reform and carbon taxes policies are implemented, there are 6,947 poor households.

With full trade reform, 5,839 poor households remain poor after trade reform and 1108 households move out of the poverty. Only 10 households move into the poverty. The findings confirm that full trade reform is a fruitful policy for poverty reduction. Partial trade reform shows impressive results; 1,134 households move out of the poverty, while only 7 households move into the poverty. Trade reform (Scenarios 1 and 2), in terms of poverty dynamics, expresses success in poverty reduction. The number of poor households that move out of poverty is greater than the number of non-poor households that move into poverty.

Lax carbon tax helps 694 poor households out of poverty, but leads 127 non-poor households into the poverty. Strict carbon tax increases the number of the poor households. Under strict carbon taxation, 4,321 non-poor households move into poverty. Considering the number of non-poor households that move into the poverty when carbon taxes are enforced, carbon taxes do not seem to do well in dealing with poverty. Therefore, using carbon tax alone is not desirable because it creates a large burden from rising numbers of poor.

A mixed policy of lax carbon tax and trade reform lifts 791 poor households out of the poverty, while 36 non-poor households move into poverty. The mixed policy of trade reform and lax carbon tax shows some success in reducing poverty. A mixed policy of strict carbon tax and trade reform shows that 3,779 non-poor households move into the poverty. Strict carbon tax has sizable negative impacts on poverty dynamics, whether it is implemented as a single policy or in combination with a trade policy. Note that these two mixed policies are not the best options for poverty reduction compared with trade policy alone, but they are better options compared with carbon taxes alone.

Table 5-3: Dynamic of the Poverty

	Number of P	P-P	P-NP	NP-P	NP-NP
Base	6,947				
S1	5,849	5,839	1,108	10	36,098
S2	5,820	5,813	1,134	7	36,101
S3	6,380	6,253	694	127	35,981
S4	10,959	6,638	309	4321	31,787
S5	6,192	6,156	791	36	36,072
S6	10,464	6,685	262	3779	32,329

Source: Author's calculation
Note: P=Poor Household, NP=Non-poor Household

In summary, among all scenarios, the partial trade reform scenario yielded the highest number of households moving out of poverty and the fewest households moving into poverty. This reveals that, in terms of poverty dynamics, partial trade reform is the most successful policy for poverty reduction compared with the other scenarios.

5.8 A Compensation for Poverty

As presented in the microsimulation results in this chapter, a strict carbon tax has adverse effects on poverty. However, since carbon tax increases government revenue, it is worth discussing the issue of government tax revenue and poverty. Table 5-4 shows changes in government revenue from carbon tax compared to changes in the incidence of poverty. The changes in poverty incidence are represented by the changes in the total poverty gap, which are calculated by multiplying the mean of the poverty gap with the total number of the poor. Results show that the poverty gap rises when a strict carbon tax is applied either individually or concurrently with trade reform. Hence, if the government desires to enforce a strict carbon tax without harming the poor, money compensation is necessary.

Table 5-4: Government Revenue from the Carbon Tax and the Poverty Incidence

	Headcount Index	**Ch.in Number of Poor** (Million)	**Mean of Poverty Gap** (Baht)	**Ch.in Poverty Gap** (Million Baht)	**Gov. Revenue from Carbon Tax** (Million Baht)	**Gov. Revenue from All Tax** (Million Baht)
Base	0.161					1,444,195
S1	0.136	-1.73	473	-816		1,151,939
S2	0.135	-1.77	468	-830		1,339,962
S3	0.148	-0.89	483	-431	524,198	1,923,513
S4	0.255	6.31	836	5,275	2,863,376	4,044,279
S5	0.144	-1.19	476	-565	536,162	1,640,430
S6	0.243	5.53	762	4,217	2,917,350	3,787,267

Source: Author's calculation

If the government applies a strict carbon tax, the revenue collected from the strict carbon tax is equal to 2,863,376 million Baht. The large amount of government revenue from a strict carbon tax can compensate the total income losses of poor households, equal to 5,275 million Baht. Thus, if the government transfers this amount of money to poor households, poor households could be moved out of the poverty. In other words, if the government chooses suitable revenue recycling, the strict carbon tax will not hurt the poor. However, it is important to note that this volume of government revenue is enormous and does not seem possible in reality. This scenario is a useful reference of an extreme case of carbon tax.

There are some important issues that need to be addressed. Firstly, considering the mixed policy of trade reform and lax carbon tax (Scenario 5), the poverty gap shows that the government does not need to compensate the poor. At the same time, government revenue from carbon tax is 536,162 million Baht, and the money can be utilized for any desired purposes, for instance, launching an environmental fund for climate change mitigation, establishing measures for poverty reduction, or setting up policies for income redistribution. Therefore, compared with the partial trade reform policy, the mixed policy is advantageous from the point of view of revenue gains, although both policies are effective in terms of economic growth, poverty reduction, and climate change.

Secondly, in view of partial trade reform (Scenario 2) and a lax carbon tax (Scenario 3), both of which were proposed in the previous chapter as neutral policies for economic growth but effective policies for GHG emissions reduction, carbon tax revenue makes the lax carbon tax policy more interesting than the partial trade reform policy. Neither policy increases poverty or GHG emissions. However, government revenues from the lax carbon tax could be utilized for various purposes, not limited to poverty and environmental concerns. Therefore, if the government uses the money to deal with the economic contraction caused by the lax carbon tax (as a slight decline in the GDP, discussed in the previous chapter) or to set up additional policies to address the income inequality arising from the carbon tax, the adverse impacts of the lax carbon tax policy would be eliminated. For example, the government could use carbon tax revenue to create jobs in non-carbon-intensive sectors. In doing so, the adverse impacts of the lax carbon tax on economic growth could be offset, and this carbon tax policy will be preferable.

5.9 Complementary Policies to Trade Reform and Carbon Tax

As discussed in the previous chapter, environmental measures in Thailand are based on a command and control approach. This study conducts two additional scenarios as representatives of the command and control approach, pollution control policy and environmental measures in the transportation sector. These two scenarios can also represent the technological change that could not be represented in the CGE analysis. Technological progress, as explained in the theoretical framework in Chapter 3, is one of the determinants of the impact of trade on the environment.

Pollution control policy, the first scenario of command and control measure, is described as the government employing command and control instruments to control emissions in carbon-intensive sectors. Consequently, producers in carbon-intensive sectors tend to adjust in several ways, for example, by introducing environmentally friendly production technology. Under this policy, the emissions intensities of carbon-intensive sectors are assumed to decrease by half. In another scenario, environmental measures in the transportation sector, the purpose of this policy is similar to the pollution control policy: to reduce emissions intensity. Environmental measures in the transportation sector is assumed to reduce emissions intensity in the transportation sector by 50%. In fact, this policy can be enforced in several ways. One example of environmental measures in the transportation sector of Thailand was a campaign encouraging substitution of gasohol for gasoline in 2001. Thailand succeeded in promoting gasohol, which emits less air pollution. For measures relating to GHG emissions, a new tax system on the automobile takes effect in 2016. Reform vehicular excise tax rates will be based on the level of CO_2 emissions rather than the size of the vehicle.

Table 5-5: Simulation Results of the Complementary Policies

	GHG Emission ($MtCO_2e$) (%Ch.)		
	No Complementary Policy	**Pollution Control Policy**	**Environmental Measures in Transportation Sector**
Base	371.91		
S1	0.09	-30.50	-6.31
S2	-0.18	-30.53	-6.45
S3	-1.74	-31.36	-7.76
S4	-13.06	-36.94	-17.94
S5	-1.65	-31.35	-7.79
S6	-13.00	-36.92	-17.98

Source: Author's calculation

The simulation results are presented in Table 5-5. The second column shows the amount of GHG emissions in all scenarios without complementary measures. The third column presents the level of GHG emissions when pollution control policy is enforced with other policy scenarios (Scenarios 1 to 6). The results show that using a pollution control policy together with other policies is beneficial for reducing GHG emissions. For example, when full trade reform is employed without the pollution control policy, GHG emissions increase by 0.09% from the base case. Full trade reform with the pollution control policy shows a reduction of GHG emissions by 30.50%. This implies that Thailand can implement full trade reform without raising GHG emissions if a pollution control policy is put in place.

For environmental measures in the transportation sector, as reported in the last column, the result reveals that GHG emissions decline in all scenarios when the measures are concurrently implemented. For instance, when environmental measures in the transportation sector are enforced along with the strict carbon tax, the GHG emissions decrease an additional 4.88% compared to the case of applying the strict carbon tax only.

In conclusion, the results show that, along with the carbon tax, which is a market-based mechanism, a command and control approach should be utilized concurrently. Since a command and control approach refers to technological development and legal pollution control, for simplicity, this study assumes there are no changes in factor returns and employment. Hence, using a command and control approach does not affect poverty and income distribution. It mitigates GHG emissions without worsening poverty and inequality problems. Policymakers concerned with poverty and inequality issues should consider command and control policy as an option instead of raising carbon tax rates. A combination of market-based instruments as well as command and control policy is a worthwhile option for GHG emissions control in Thailand.

5.10 Conclusions

The results of the analysis in this chapter can be summarized as follows.

First, both full trade reform and partial trade reform are good for poverty reduction but not for income distribution. However, considered comprehensively, the poverty dynamic reveals that partial trade reform is more successful in moving the poor out of poverty. Therefore, in terms of poverty and inequality issues, partial trade reform seems to be preferable to full trade reform.

Second, a combined policy of lax carbon tax and full trade reform, which was proposed in the previous chapter as an appropriate policy for protecting the environment while enjoying the benefits of international trade, is good for poverty reduction but increases inequality.

Third, the degree of carbon tax is important for addressing poverty and inequality concerns. The carbon tax decreases poverty at low tax rates and increases poverty at high tax rates. With regard to inequality, there is a U-shaped relationship between carbon tax and inequality. Thus, the carbon tax rate should be emphasized in order to avoid strengthening inequality.

Fourth, the lax carbon tax and partial trade reform, which show comparable impacts for the economy and GHG emissions, as discussed in Chapter 4, also have positive effects on poverty and negative impacts on income distribution. Each policy has its advantage. Partial trade reform is more successful at poverty reduction than the lax carbon tax. However, considering government revenue from carbon tax, the lax carbon tax generates money that the government can utilize for the desired purpose. With appropriate revenue recycling, carbon tax revenue may be useful for enhancing economic growth and reducing income inequality. In doing so, the drawbacks of the carbon tax, such as economic contraction and degradation of income distribution, are removed.

Fifth, for income distribution, both trade reform and the carbon tax increase the inequality problem. The government must realize this and implement these policies carefully.

Finally, supplementary policy such as environmental regulations and any policies that encourage technological progress should be promoted. If supplementary policies are implemented, Thailand can enjoy the benefits of an additional reduction in GHG emissions without suffering from an increase in poverty and income inequality, compared to the case where no complementary policies are enforced.

Chapter 6: Conclusions

6.1 Summary of the Study

Due to climate change awareness, Thailand agreed to shift its development goals from economic growth to sustainable development. Sustainable development was initiated as the main development goal in the 11th National Economic and Social Development Plan (2012-2016). Under this development plan, establishment of a green economy and society was discussed. The concept of a green economy includes encouraging green production and consumption of low carbon products. A reduction or mitigation of GHG emissions is an important target.

International trade has been the primary source of economic growth in Thailand over the past three decades. Thailand's international trade policy is on track to free trade, as policies emphasize export promotion and trade agreements. Historical statistics indicate that Thailand would succeed in using free trade policy or trade reform to promote economic growth and poverty reduction, but with climate change concerns, the question arises of whether trade reform would increase GHG emissions. Therefore, if Thailand wishes to move toward sustainable development goals that underline a green economy, trade reform needs to be revised.

To reexamine trade reform with climate change considerations in mind, the impacts of trade reform in multiple dimensions relating to GHG emissions, poverty, and income distribution are assessed. The results give us knowledge that is useful for proposing a trade policy that offers compromises between climate change considerations and economic growth.

There are two objectives of the study. The first objective is to analyze the impacts of trade reform on GHG emissions in Thailand when implemented with and without a carbon tax. The second objective is to assess the impacts of trade reform in a similar way, but the impacts on poverty and income distribution are taken into account.

In Chapter 2, this study presented the background of the Thai economy, showing that when international trade was promoted as a central strategic policy for enhancing the economic growth of Thailand, a change in trade structure occurred. Thailand's exports shifted towards the heavy manufacturing sector. As a result of the trade structure change, the economic structure of Thailand adjusted accordingly. The manufacturing sector surpassed the agricultural sector both in production and exports. Trade also enlarged the transportation sector. The expansion of manufacturing activity, especially heavy manufacturing, and transportation activity highlighted questions on environmental impacts, including the rapid increase of GHG emissions. In the company of economic growth and structural change, the volume of GHG emissions increases continuously. To date, Thailand does not have direct measures for dealing with GHG emissions. Market-based measures such as a pollution surcharge and a carbon tax are scheduled to launch shortly. Note that rapid economic growth during the trade promotion period had positive impacts on poverty and income distribution. If the carbon tax is enforced, poverty and income distribution will tend to change, since the carbon tax redistributes the income of agents in the economy.

Chapter 3 described the data and the model used in this study. This study applied Löfgren, Harris, and Robinson's (2001) standard Computable General Equilibrium (CGE) model from the International Food Policy Research Institute. The CGE model is calibrated with the Social Accounting Matrix (SAM) of Thailand extracted from the database of the Global Trade Analysis Project (GTAP) version 8. The CGE analysis is applied to investigate the impacts of trade reform on GHG emissions in Thailand in Chapter 4. The impacts of trade reform when imposed with and without carbon tax are assessed under six scenarios. Scenario one is a simulation of full trade reform; tariffs are removed across the sectors. Scenario two is a simulation of trade reform policy in carbon-intensive sectors, or partial trade reform. Scenario three is a simulation of the lax carbon tax without trade reform. Scenario four is a simulation of the strict carbon tax without trade reform. Scenario five addresses full trade reform with the lax carbon tax. Scenario six is a mixed policy of full trade reform and strict carbon tax. Results from the CGE analysis are used to calculate levels of GHG emissions using sectoral GHG emissions intensity values. Analytical results reveal that full trade reform enhances economic growth, but Thailand has to accept an increase in GHG emissions at the same time. The adverse impacts of full trade reform can be eliminated by introducing a carbon tax. The degree of a carbon tax is important. A strict carbon tax substantially reduces GHG emissions but leads to economic contraction. A lax carbon tax is desirable for Thailand. Findings also indicate that partial trade reform contributes benefits both for boosting economic growth and reducing GHG emissions. Thus, to impose a trade reform policy with climate change considerations, there are two possible solutions: the mixed policy of full trade reform and lax carbon tax or the partial trade reform policy.

The impacts of trade reform and carbon tax on poverty and income distribution in Thailand are examined in Chapter 5. Results from the CGE simulation are utilized further in microsimulations to measure changes in the incidence of poverty. A calculation of changes in poverty is done at the household level. The household data are from the 2005 Household Socio-Economics Survey (SES), and were collected by the Thailand National Statistical Office (NSO). Microsimulation results show that both full and partial trade reform is beneficial for poverty reduction but worthless for income distribution. Partial trade reform is somewhat more successful than full trade reform to reduce poverty and redistribute income. Lax carbon tax implementation shows similar outcomes. It reduces poverty but increases income inequality in Thailand. Similar to the GHG emissions analysis, the degree of carbon tax is significant. Strict carbon tax adversely affects poverty and income distribution. A review of the two policies that are successful in reducing GHG emissions and boosting economic growth—partial trade reform and the policy package combining the lax carbon tax and full trade reform—reveals that partial trade reform is slightly more successful at poverty reduction than the mixed policy. An analysis of poverty dynamics confirms the findings. Compared with other policy scenarios, the partial trade reform policy contributes the greatest advantage for poverty reduction. The number of poor households moving out of poverty is the largest and the number of households moving into poverty is the lowest under this policy. It is important to note that although the mixed policy of trade reform and carbon tax seems to yield fewer benefits than the partial trade reform policy in terms of poverty reduction, it generates government revenue from carbon tax, which the government can utilize for desired purposes. For example, government can use carbon tax revenue to launch a fund to cope with climate change, enhance economic growth, and offset poverty and income distribution effects. With the right revenue recycling, the drawbacks of carbon tax can be removed.

Apart from the six scenarios previously discussed, two more scenarios, pollution control policy and environmental measures in the transportation sector, which illustrate the command and control strategy, are taken into account. The two additional scenarios denote technological progress, which cannot be visualized with the CGE analysis. Pollution control policy is defined as government use of the command and control approach to regulating GHG emissions in the carbon-intensive sector. Consequently, producers in the carbon-intensive sector adjust their production toward low-carbon production technology. The emissions intensity of carbon-intensive sectors is assumed to decrease by half, as representative of technological progress. Environmental measures in the transportation sector are similar to the pollution control policy except that the government imposes the policy in the transportation sector only, and the emissions intensity of the transportation sector is reduced, while other sectors remain the same. These two scenarios are integrated with the prior six scenarios. Results show that integrating command and control policy with other policies is helpful for reducing GHG emissions. As the command and control approach refers to technological development or legal pollution controls, it is assumed that there is no change in factor returns and employment. Thus, using a command and control strategy does not affect poverty and income distribution.

The findings from Chapter 4 and Chapter 5 can answer our research questions. The first question was “What are the impacts of trade reform on the economy, GHG emissions, poverty, and income distribution of Thailand?” The results show that trade reform increases the GDP, exports, imports, and welfare. It reduces poverty but worsens income equality. For environmental impacts, impacts are different depending on the characteristics of the trade reform. If trade reform is carried out across the sectors, GHG emissions increase. In contrast, GHG emissions decline when trade reform is performed in the carbon-intensive sector only.

The questions “Under trade reform, is carbon tax a necessary measure to control climate change by controlling GHG emissions?” and “If it is necessary, to what extent should the carbon tax be applied?” can also be answered. The carbon tax is important to deal with an increase in GHG emissions under full trade reform. The lax carbon tax is worth imposing along with full trade reform to control GHG emissions because it does not cause a large burden on the economy and poverty. Strict carbon tax causes economic contraction and increases poverty. Thus, strict carbon tax should not be implemented. However, if partial trade reform is introduced, carbon tax is not necessary.

Discussion of the research findings also provides a solution for the main research question “Does trade reform really benefit Thailand when climate change and poverty are considered?” Trade reform is worthwhile for Thailand, but it has to be applied carefully. The first policy option to ensure benefits from trade reform is removing tariffs in carbon-intensive sectors only, or partial trade reform. This policy raises national income, reduces poverty, and controls GHG emissions concurrently. That is, partial trade reform achieves economic growth targets with compromising climate change and poverty. The second policy option is a policy package including full trade reform and a lax carbon tax. Full trade reform should not be introduced independently if climate change is a concern. A complementary policy like carbon tax must be introduced concurrently. Trade reform deals with economic and poverty matters, while carbon tax copes with the climate change problem.

6.2 Policy Implications

This study has analyzed the trade reform policy of Thailand with climate change and poverty considerations in Chapters 4 and 5. The results suggest that there are several areas for improvement, as follows:

I. Partial trade reform is an appropriate trade policy for Thailand when climate change is taken into account.

Policymakers should reexamine trade policy. Trade reform should not be imposed across all sectors if climate change and poverty issues are concerns. Full trade reform, although it encourages economic growth and reduces poverty in Thailand, shifts the economic structure towards carbon-intensive industry and increases GHG emissions. Partial trade reform—tariff reductions only in the carbon-intensive sector—confers benefits on economic growth and poverty without increasing the burden from GHG emissions. Thus, partial trade reform should be promoted.

II. The country should adopt the mixed policy of full trade reform and lax carbon tax

If full trade reform is implemented individually, the expansion of trade shifts the economic structure of Thailand towards carbon-intensive sectors. Hence, if climate change is considered, the carbon tax should be enforced in order to avoid environmental pressure from growing GHG emissions after trade reforms are introduced. Thailand should adopt a mixed policy package that includes full trade reform with lax carbon tax. Tariff reductions and lax carbon tax should be introduced simultaneously.

With climate change concerns, the mixed policy is a good solution. With the mixed policy, there is a gain in efficiency from reduced tariffs, combined with a decrease in GHG emissions from the application of the carbon tax. With the mixed policy, the advantages to economic growth and the reduction in poverty from trade reform remain, and GHG emissions are controlled. Thailand can pursue economic development without serious climate change.

There is another advantage of the mixed policy. Recall that trade reform contributes benefits to economic growth and poverty reduction, while the carbon tax, although it has positive impacts in dealing with climate change, has undesirable impacts on the economy and poverty. If Thailand is obligated to introduce a carbon tax in the future (for instance, as the environmental measures to reduce GHG emissions reach the target of the United Nations

Framework Convention on Climate Change [UNFCCC]), it should be enforced together with a trade reform policy. Implementing the mixed policy is more beneficial to the economy than enforcing carbon tax alone.

III. Revenue recycling is important and should be chosen carefully.

An implementation of carbon tax raises government revenue. Carbon tax revenue is favorable for two reasons. Firstly, it provides money to compensate revenue loss from tariff removal and to stabilize the fiscal balance. Secondly, carbon tax revenue can be utilized for several purposes, depending on government objectives. In general, carbon tax revenue is typically used for climate change purposes, for example, establishing an environmental fund to promote renewable energy. However, as this study's findings show, the carbon tax has a negative impact on poverty and income distribution. The government could consider sharing some of the carbon tax revenue to deal with these issues; for instance, a money transfer program for the poor, who face severe poverty from carbon tax applications, could be instituted. That is, if the government chooses suitable revenue recycling, the country could experience gains in both environmental and poverty issues at the same time.

IV. The country should encourage technological progress

Thailand should encourage technological progress, particularly low carbon technology. Advanced technology allows manufacturers to carry out production with lower GHG emissions. Implementing low carbon technology supports GHG mitigation without worsening poverty and inequality problems.

Encouraging technological progress can be accomplished in many ways, for instance, promoting energy efficiency, supporting renewable energy, and controlling GHG emissions through legal regulations. Measures for supporting technological progress need not be market-based mechanisms like carbon tax. A complementary policy such as command and control measures can be promoted.

Based on our findings, along with market-based mechanisms like carbon tax, command and control measures can be implemented. Command and control measures in this study refer to an emissions control policy in emissions-intensive sectors, and environmental measures in the transportation sector. Findings indicate that adding a pollution control policy as a supplementary policy adds benefits for reducing GHG emissions. As a high carbon tax causes a large burden on the economy and the poor, policymakers who are concerned with these issues should consider command and control policies as an option to increasing carbon tax rates. Thus, a combination of market-based instruments and command and control policy is a worthwhile option for GHG emissions control in Thailand.

V. There are no universal policy packages that achieve all development goals

Results of the study highlight the significance of implementing policy in a "package," particularly when multiple development targets are established. Each policy has its advantages. Policymakers must realize this and implement a policy package that corresponds to the targets.

For example, if poverty, climate change, and economic growth are expressed as concerns simultaneously, there are at least two policy options that provide possible solutions to reach the targets: the partial trade reform policy and the mixed policy of full trade reform and lax carbon tax. The former policy allows Thailand to achieve economic growth, climate change control, and poverty reduction. In the latter, trade reform deals with economic and poverty matters, while the carbon tax copes with climate change problems. Accordingly, the mixed policy can help Thailand reach its targets just as partial trade reform can. However, there is a difference in the impacts of these two policies. Partial trade reform is preferred in terms of poverty and income distribution. The mixed policy generates government revenue from carbon tax, which can be utilized in various ways, for example, to offset poverty and improve income distribution.

It is important to note that both the mixed policy and the partial trade reform policy reinforce unequal income distribution. Policymakers concerned with the issue of income inequality should look for other supplementary policy to cope with the problem.

In conclusion, it is not sensible draw conclusions about which policy is “right” for Thailand. Each policy has its advantages. Policymakers must be aware of this fact and implement policies that correspond to their target.

6.3 Limitations of the Study and Suggestions for Future Research

Using the CGE analysis and the CGE-microsimulation method in this study, the impacts of trade reform on the economy, GHG emissions, and social issues such as poverty and income distribution are determined. The findings answer the research questions. Free trade is good for economic growth and poverty reduction, but not for income distribution and the environment. Trade reform should be implemented carefully and complementary policy should be imposed. However, this study is a basic step in analyzing the impacts of trade in multiple dimensions, not only the economic impacts. There are various issues that should be improved in future research in order to develop a more realistic model.

With the simple CGE approach, the limitations of this study mostly derive from the limitations of the data, data manipulation, and the difficulty of structuring the model. The limitations are as follows:

i. The CGE model should be restructured. The model worked with several assumptions. Some assumptions of the model may not effectively explain the real situation, such as perfect competition in the goods market and full employment conditions on the factor market. These assumptions should be modified in future research.

   Some key assumptions involving emissions need to be emphasized here. The first concern is that the Leontief specification utilizes intermediate inputs, which do not allow substitution of input uses when relative prices change. So, producers cannot substitute between carbon-intensive and non-carbon-intensive inputs. Hence, when carbon tax is imposed, the producer tends to reduce the level of production instead of adjusting input uses toward low-carbon production.

The second concern is that the consumption pattern of institutions does not change after income and the price of goods change. This assumption may differ from economic theory, where consumers tend to demand environmentally friendly goods when their income increases. The third concern is the value of the parameters used in the CGE model. This study utilizes the estimated parameters from the GTAP and previous literature, for instance, the elasticity of substitution from the GTAP8. If the values of the estimated parameters are not precise, the CGE results will not be accurate, accordingly.

ii. The climate change indicator, GHG emissions, should be incorporated in the model. GHG emissions translate to social costs and social benefits, which should be included in the model and be part of consumer and producer optimization. In addition, merging GHG emissions with the model will link emissions levels with carbon tax straightforwardly. In this study, under limited time, GHG emissions are evaluated outside the CGE model. It is essential to note that calculating GHG emissions exogenously is also widely accepted.

iii. The model cannot explain the role of "technological progress" which is, theoretically, an important factor in determining the level of GHG emissions. It would be more useful if the technology variable were incorporated in the model. This study does not take into account the technology variable, in order to simplify the CGE model. This limitation may lead to results that are biased towards negative effects. The CGE results for environmental impacts in this study may be overestimated. In a future study, in order to grasp the impacts of trade reform completely, a model that considers technological progress should be developed.

iv. GHG emissions may be a quality indicator of climate change. However, the impacts of trade on the environment are not limited to climate change only. This study cannot analyze the impacts of trade on other environmental indicators, such as pollution and resource depletion, due to limitations in the data. In reality, environmental degradation affects the standard of living, health, and welfare, and should be emphasized. Future studies should focus on these topics if the data is available.

v. The data should be updated. The most recent social accounting matrix data is based on the 2005 input-output table by the National Economic and Social Development Board of Thailand. Thus, although it is the latest data, the data engaged in the study is not up to date. Subsequently, analytical results may not represent the actual circumstances of the Thai economy. The research on this topic should be reexamined when updated data is accessible.

vi. In this study, the impacts of trade reform on poverty and income distribution are transmitted via changes in the prices of goods and changes in factor returns. The impacts of labor migration, for instance, when workers move to work in other sectors, are not taken into consideration. This limitation is important in terms of poverty analysis. If there is evidence to support that labor movement is important for Thailand, this issue should be integrated in the model. A non-parametric microsimulation approach that can deal with this difficulty should be implemented.

vii. Last but not least, to contribute more knowledge, studies on trade and climate change issues should not be limited to the national level. A study on ecological footprints should be addressed in a future study. International trade can be identified by a nation's ecological footprint, which results in lower emissions and reduced natural resource use at the global level.

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APPENDICES

Appendix A: Overview of the Standard Computable General Equilibrium (CGE) Model (Löfgren et al., 2001)

In chapter 3, the standard CGE conceptual model used for the CGE analysis in this study was discussed. This section clarifies the model's structure in mathematical terms. The standard CGE model was not developed for any specific country, but a compatible social accounting matrix (SAM) is required for model calibration. To apply the standard CGE model, the SAM of a designated country must be established and adjusted to correspond to the model's SAM format. In this study, the Thailand SAM extracted from the database of the Global Trade Analysis Project (GTAP) version 8 is modified and applied to the standard CGE model. In order to have a model that replicates the characteristics of the Thai economy, some features of the standard CGE model have also been modified. The modifications to the standard CGE model are explained along with the model structure discussion below.

The model contains a set of non-linear simultaneous interlinked equations, which can be categorized into four groups: price block, production and trade block, institution block, and system constraint block. At the beginning, the notation principles used in the model are summarized. Then, each equation block is discussed in sequence.

Item	**Notation**
Endogenous variables	Upper-case Latin letters without a bar
Exogenous variables	Upper-case Latin letters with a bar
Parameters	Lower-case Latin letters (with or without a bar) or lower-case Greek letters (with or without superscripts)
Set indices	Lower-case Latin letters as subscripts to variables and Parameters

SETS

$\alpha \in A$	activities
$\alpha \in ACES(\subset A)$	activities with a CES function at the top of the technology nest
$\alpha \in ALEO(\subset A)$	activities with a Leontief function at the top of the technology nest
$c \in C$	commodities
$c \in CD(\subset C)$	commodities with domestic sales of domestic output
$c \in CDN(\subset C)$	commodities not in CD
$c \in CE(\subset C)$	exported commodities
$c \in CEN(\subset C)$	commodities not in CE
$c \in CM(\subset C)$	imported commodities
$c \in CMN(\subset C)$	commodities not in CM
$c \in CT(\subset C)$	transactions service commodities
$c \in CX(\subset C)$	commodities with domestic production
$f \in F$	factors
$i \in INS$	institutions (domestic and rest of the world)
$i \in INSD(\subset INS)$	domestic institutions
$i \in INSDNG(\subset INSD)$	domestic nongovernment institutions
$h \in H(\subset INSDNG)$	households

PARAMETERS

Latin letters

$cwts_c$	weight of commodity *c* in the *CPI*
$dwts_c$	weight of commodity *c* in the producer price index
$ica_{c\,a}$	quantity of *c* as intermediate input per unit of activity *a*
$icd_{c\,c'}$	quantity of commodity *c* as trade input per unit of *c'* produced and sold domestically
$ice_{c\,c'}$	quantity of commodity *c* as trade input per exported unit of *c'*

$icm_{c\,c'}$	quantity of commodity *c* as trade input per imported unit of *c'*
$inta_a$	quantity of aggregate intermediate input per activity unit
iva_a	quantity of value-added per activity unit
$\overline{mps_i}$	base savings rate for domestic institution *i*
$mps01_c$	0-1 parameter with 1 for institutions with potentially flexed direct tax rates
pwe_c	export price (foreign currency)
pwm_c	import price (foreign currency)
$qdst_c$	quantity of stock change
$\overline{qg_c}$	base-year quantity of government demand
$\overline{qinv_c}$	base-year quantity of private investment demand
$shif_{i\,f}$	share for domestic institution *i* in income of factor *f*
$shii_{i\,i'}$	share of net income of *i'* to *i* $\left(i' \in INSDNG'; i \in INSDNG\right)$
ta_a	tax rate for activity *a*
te_a	export tax rate
tf_f	direct tax rate for factor *f*
$\overline{tins_i}$	exogenous direct tax rate for domestic institution *i*
$tins01_i$	0-1 parameter with 1 for institutions with potentially flexed direct tax rates
tm_c	import tariff rate
tq_c	rate of sales tax
$trnsfr_{i\,f}$	transfer from factor *f* to institution *i*
tva_a	rate of value-added tax for activity *a*

Greek Letters

α_a^a	efficiency parameter in the CES activity function
α_a^{va}	efficiency parameter in the CES value-added function
α_a^{ac}	shift parameter for domestic commodity aggregation function

α_c^q	Armington function shift parameter
α_c^t	CET function shift parameter
$\beta_{a\,c\,h}^h$	marginal share of consumption spending on home commodity *c* from activity *a* for household *h*
$\beta_{c\,h}^m$	marginal share of consumption spending on marketed commodity *c* for household *h*
δ_a^a	CES activity function share parameter
$\delta_{a\,c}^{ac}$	share parameter for domestic commodity aggregation function
δ_c^q	Armington function share parameter
δ_c^t	CET function share parameter
δ_{fa}^{va}	CES value-added function share parameter for factor *f* in activity *a*
γ_{ch}^m	subsistence consumption of marketed commodity *c* for household *h*
$\gamma_{a\,c\,h}^h$	subsistence consumption of home commodity *c* from activity *a* for household *h*
θ_{ac}	yield of output *c* per unit of activity *a*
ρ_a^a	CES production function exponent
ρ_a^{va}	CES value-added function exponent
ρ_c^{ac}	domestic commodity aggregation function exponent
ρ_c^q	Armington function exponent
ρ_c^t	CET function exponent

EXOGENOUS VARIABLES

$\overline{CPI}$	consumer price index
$\overline{DTINS}$	change in domestic institution tax share (= 0 for base; exogenous variable)
$\overline{FSAV}$	foreign savings (FCU)
$\overline{GADJ}$	government consumption adjustment factor

$\overline{IADJ}$	investment adjustment factor
$\overline{MPSADJ}$	savings rate scaling factor (= 0 for base)
$\overline{QFS}_f$	quantity supplied of factor
$\overline{TINSADJ}$	direct tax scaling factor (= 0 for base; exogenous variable)
$\overline{WFDIST}_{f\,a}$	wage distortion factor for factor *f* in activity *a*

ENDOGENOUS VARIABLES

$DMPS$	change in domestic institution savings rates (= 0 for base; exogenous variable)
DPI	producer price index for domestically marketed output
EG	government expenditures
EH_h	consumption spending for household
EXR	exchange rate (*LCU* per unit of *FCU*)
$GOVSHR$	government consumption share in nominal absorption
$GSAV$	government savings
$INVSHR$	investment share in nominal absorption
MPS_i	marginal propensity to save for domestic nongovernment institution
PA_a	activity price (unit gross revenue)
PDD_c	demand price for commodity produced and sold domestically
PDS_c	supply price for commodity produced and sold domestically
PE_c	export price (domestic currency)
$PINTA_a$	aggregate intermediate input price for activity *a*
PM_c	import price (domestic currency)
PQ_c	composite commodity price
PVA_a	value-added price (factor income per unit of activity)
PX_c	aggregate producer price for commodity
$PXAC_{a\,c}$	producer price of commodity *c* for activity *a*

QA_a	quantity (level) of activity
QD_c	quantity sold domestically of domestic output
QE_c	quantity of exports
$QF_{f\,a}$	quantity demanded of factor *f* from activity *a*
QG_c	government consumption demand for commodity
$QH_{c\,h}$	quantity consumed of commodity *c* by household *h*
$QHA_{a\,c\,h}$	quantity of household home consumption of commodity *c* from activity *a* for household *h*
$QINTA_a$	quantity of aggregate intermediate input
$QINT_{c\,a}$	quantity of commodity *c* as intermediate input to activity *a*
$QINV$	quantity of investment demand for commodity
QM_c	quantity of imports of commodity
QQ_c	quantity of goods supplied to domestic market (composite supply)
QT_c	quantity of commodity demanded as trade input
QVA_a	quantity of (aggregate) value-added
QX_c	aggregated marketed quantity of domestic output of commodity
$QXAC_{a\,c}$	quantity of marketed output of commodity *c* from activity *a*
$TABS$	total nominal absorption
$TINS_i$	direct tax rate for institution $i\left(i \in INSDNG\right)$
$TRII_{i\,i'}$	transfers from institution *i.* to *i* (both in the set INSDNG)
WF_f	average price of factor *f*
YF_f	income of factor *f*
YG	government revenue
YI_i	income of domestic nongovernment institution
$YIF_{i\,f}$	income to domestic institution *i* from factor *f*

Price Block

This section expresses a set of equations in which endogenous model prices are linked to other prices. Equation (1) shows that import price is defined by local currency units. Import price is determined by world import price, exchange rate, import tariff rate, and transaction cost. With the small country assumption, world import price is considered as an exogenous variable.

An import tariff rate (tm_c) is important because it is a variable that represents the degree of trade reform. Recalling the simulation scenarios of this study, there are two scenarios involving trade reform: full trade reform (scenario 1) and partial trade reform (scenario 2). For the full trade reform scenario, the import tariff rate is set to be zero across commodities, and for partial trade reform, it is equal to zero for only the carbon-intensive sector. Reducing the import tariff is anticipated to reduce import prices. Equation (2) shows export price in local currency units. Analogous with equation (1), the export price of any commodity is linked with the world export price, exchange rates, export taxes, and transaction costs. For non-traded goods, as presented in equation (3), the domestic demand price is the domestic supply price plus transaction costs. Equation (4) represents absorption, the total domestic spending at domestic demand prices. It represents the value of composite goods, which is the sum of the value of imports and domestically produced goods. Composite prices, the prices that clear the domestic market, can be obtained by dividing equation (4) by $(1+tq_c).QQ_c$. Considering domestically produced goods, equation (5), the market output value of a given commodity is equal to the sum of the value of domestic sales and exports. The producer prices are implicitly defined in equation (5) and can be acquired by dividing equation (5) by QX_c.

Import price $$PM_c = pwm_c.(1+tm_c).EXR + \sum_{c' \in CT} PQ_{c'}.icm_{c'c} \qquad c \in CM \qquad (1)$$

Export price $$PE_c = pwe_c.(1-te_c).EXR - \sum_{c' \in CT} PQ_{c'}.ice_{c'c} \qquad c \in CE \qquad (2)$$

Demanded price of nontraded goods	$PDD_c = PDS_c + \sum_{c' \in CT} PQ_{c'}.icd_{c'c}$	$c \in CD$	(3)
Absorption	$PQ_c(1-tq_c).QQ_c = PDD_c.QD_c + PM_c.QM_c$	$c \in (CU \cup CM)$	(4)
Marketed output value	$PX_c.QX_c = PDS_c.QD_c + PE_c.QE_c$	$c \in CX$	(5)

For domestic production activity, the aggregate output of any commodity comes from an accumulation of the commodity output of different activities subject to a fixed yield coefficient. An activity price, equation (6), is defined as the producer price of commodity *c* for activity *a* multiplied by yields of commodity *c* per unit of activity *a*. Recall that the producer will maximize profit by choosing a combination of aggregate intermediate inputs and value added. Prices of aggregate intermediate inputs and value added are considered in the following equations. Equation (7) specifies that the price of the aggregate intermediate input of activity *a* is subject to composite commodity prices and an intermediate input coefficient. Equation (8) shows that, for each activity, total revenue is fully exhausted by payments for value-added and intermediate inputs. Indirectly, the value-added prices could be obtained by manipulating this equation. Activity tax (ta_a) in equation (8) is utilized for simulation of carbon tax (scenarios 3 to 6). Following the method proposed by McDougall (1993) and Wattanakuljarus and Wongsa (2011), the designated carbon tax rate is converted into an ad-valorem equivalent. Then, the activity tax can be modified using the ad-valorem equivalent.

Activity price	$PA_a = \sum_{c \in c'} PXAC_{a\,c}.\theta_{a\,c}$	$a \in A$	(6)
Aggregate intermediate input price	$PINTA_a = \sum_{c \in C} PQ_c.ica_{c\,a}$	$a \in A$	(7)
Activity revenue and costs	$PA_a(1-ta_a).QA_a = PVA_a.QVA_a + PINTA_a.QINTA_a$	$a \in A$	(8)

Production and Trade Block

This section discusses production equations and the allocation of outputs. At the top level, as mentioned above, the producer will maximize profit by selecting a combination of value-added and aggregate intermediate inputs subject to an existing technology and the prices of factor inputs and outputs. The Leontief function is assumed for production at the top level. Equations (9) and (10) show that demands for value-added inputs and aggregate intermediate inputs are linked with the relative prices of the two inputs.

Leontief technology: Demand for aggregate value-added	$QVA_a = iva_a.QA_a$	$a \in ALEO$	(9)
Leontief technology: Demand for aggregate intermediate input	$QINTA_a = inta_a.QA_a$	$a \in ALEO$	(10)

At the bottom level, the value added is specified as CES technology, as presented in equation (11). Equation (12) reveals the factor demand function. Each activity demands factors up to the point where the marginal revenue product of each factor is equal to its marginal cost or the factor price. For intermediate inputs, equation (13) denotes disaggregated intermediate input demand. A substitution among intermediate inputs is assumed to follow the standard Leontief specification. Disaggregated intermediate input demand is equal to the level of aggregate intermediate input use times a fixed intermediate input coefficient.

Value-added and factor demands	$QVA_a = \alpha_a^{va}\left(\sum_{f\in F}\delta_{f\,a}^{va}.QF_{f\,a}^{-\rho_a^{va}}\right)^{\frac{1}{1+\rho_a^{a}}}$	$a \in A$	(11)
Factor demand	$WF_f.\overline{WFDIST_{f\,a}} = PVA_a(1-tva_a).QVA_a\left(\sum_{f\in F'}\delta_{f\,a}^{va}.QF_{f\,a}^{-\rho_a^{va}}\right)^{-1}\delta_{f\,a}^{va}.QF_{f\,a}^{-\rho_a^{va}-1}$	$a \in A$ $f \in F$	(12)

Disaggregated intermediate input demand	$QINT_{c\,a} = ica_{c\,a} . QINTA_a$	$a \in A$ $c \in C$	(13)

Equations (14) to (23) present the flows of commodities. Commodity outputs produced from activity are allocated to market sales and home consumption, as stated in equation (14). Note that this study assumes all outputs are sold in the market, due to the limited data on home consumption. Following the assumption that a commodity can be produced by one or more activities, equation (15) addresses the aggregated output of a given commodity, which is a function of output at the activity level. Equation (16) implicitly states that the marginal cost of commodity *c* from activity *a* is equal to the marginal revenue product of commodity *c* from activity *a*. Activity-specific commodity prices serve to clear the implicit market for disaggregated commodities.

Equations (17) and (18) denote the distribution of domestically produced aggregate outputs to domestic and export markets. Imperfect transformability between the aggregate outputs of these two markets is assumed. See below where equations (20) to (22) are described. Equation (18) shows the distribution of aggregate outputs with regard to the prices of the outputs in both the domestic and export markets and the constant elasticity of transformation (CET) function parameter. For a commodity that does not have both exports and domestic sales, equation (19) is applied.

Equations (20), (21), and (22) focus on composite commodities, which consist of domestic sales and imports. Domestic and import commodities are assumed to be imperfect substitutions with reference to the constant elasticity of substitution (CES) aggregation function. Alternatively speaking, demands for imports and domestic goods can be expressed by the Armington function. The demands of two goods are derived under the assumption that domestic demander minimizes the budget subject to imperfect substitutability. Equation (21) shows that the demands for imports and domestic products are linked with the relative prices of the two goods and the Armington function parameter. A commodity that has either import or domestic sales, but not both, can be explained by equation (22). In the presence of transaction services, equation (23) should be utilized. It reveals that the demand for transaction services is the sum of demands for transaction services from imports, exports, and domestic sales.

Commodity production and allocation	$QXAC_{a\,c} + \sum_{h \in H} QHA_{a\,c\,h} = \theta_{a\,c} QA_a$	$a \in A$ $a \in CX$	(14)
Output aggregation function	$QX_c = \alpha_c^{ac} \left(\sum_{a \in A} \delta_{a\,c}^{ac} . QXAC_{a\,c}^{-\rho_c^{ac}} \right)^{-1/\rho_a^{ac} - 1}$	$c \in CX$	(15)
First-order condition for output aggregation function	$PXAC_{a\,c}$ $= PX_c . QX_c \left(\sum_{a \in A'} \delta_{a\,c}^{ac} . QXAC_{a\,c}^{-\rho_c^{ac}} \right)^{-1} \delta_{a\,c}^{ac} . QXAC_{a\,c}^{-\rho_c^{ca} - 1}$	$a \in A$ $c \in CX$	(16)
Output transformation (CET) function	$QX_c = \alpha_a^t . \left(\delta_a^t . QE_c^{\rho_c^t} + (1 - \delta_c^t) . QD_c^{-\rho_c^t} \right)^{-1/\rho_c^t}$	$a \in (CE \cap CD)$	(17)
Export-domestic supply ratio	$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} . \frac{1 - \delta_c^t}{\delta_c^t} \right)^{1/\rho_c^t - 1}$	$c \in (CE \cap CD)$	(18)
Output transformation for non-exported commodities	$QX_c = QD_c + QE_c$	$c \in (CD \cap CEN$ $\cup (CE \cap CDN$	(19)
Composite supply (Armington) function	$QQ_c = \alpha_c^q . \left(\delta_c^q . QM_c^{-\rho_c^q} + (1 - \delta_c^q) . QD_c^{-\rho_c^q} \right)^{-1/\rho_c^q}$	$c \in (CM \cap CD)$	(20)
Import-domestic demand ratio	$\frac{QM_c}{QD_c} = \left(\frac{PDD_c}{PM_c} . \frac{\delta_c^q}{1 - \delta_c^q} \right)^{1/1+\rho_c^q}$	$c \in (CM \cap CD)$	(21)
Composite supply for non-imported outputs and imports	$QQ_c = QD_c + QM_c$	$c \in (CD \cap CMN$ $\cup (CM \cap CDN$	(22)
Demand for transactions services	$QT_c = \sum_{c' \in C'} \left(icm_{c\,c'} . QM_{c'} + ice_{c\,c'} . QE_{c'} + icd_{c\,c'} . QD_{c'} \right.$	$c \in CT$	(23)

Institution Block

The institution block expresses the elements of the model that relate to institutions. There are four institutions in the model (households, enterprises, the government, and the rest of the world). To summarize, households and enterprises receive income from two sources: the factors of production and transfers from other institutions. Government revenue comes from taxes and transfers from other institutions. Transfer from the rest of the world is assumed to be fixed.

Equations (24) to (30) are about the income and expenditure of domestic non-government institutions (households and enterprises). As mentioned earlier, one of the sources of household and enterprise income is factor income. Equation (24) expresses the total factor income categorized by input factor types. The income of factor *f* is the sum of activity payments. Note that there are two variables that denote factor wages: an economy-wide wage variable and an activity-specific wage variable. An economy-wide wage variable is considered flexible and serves to the clear factor market. Activity-specific wages are fixed and different across activities. The two wage variables play important roles in dealing with factor market closure.

In equation (25), factor income is split among domestic institutions in fixed shares after payment of direct factor taxes and transfers to the rest of the world. For a given domestic non-government institution, total income, which is expressed in equation (26), is the sum of factor income, transfers from other domestic non-government institutions, transfers from government, and remittances from abroad. Transfers among domestic non-government institutions are explained in detail in equation (27).

Factor incomes	$YF_f = \sum_{a \in A} WF_f . \overline{WFDIST}_{f\,a} . QF_{f\,a}$	$f \in F$	(24)
Institutional factor incomes	$YIF_{i\,f} = shif_{i\,f} \left[1 - tf_f . YF_f - transfr_{row\,f} EXR \right]$	$i \in INSD$ $f \in F$	(25)

Income of domestic, nongovernment institutions	$YI_i = \sum_{f \in F} YIF_{i\,f} + \sum_{i' \in INSDNG'} TRII_{i\,i'} + trnsfr_{i\,gov}.\overline{CPI}$ $+trnsfr_{i\,row}.EXR$	$i \in INSDNG$	(26)
Intra-institutional transfer	$TRII_{i\,i'} = shii_{i\,i'}.(1-MPS_{i'}).(1-TINS_{i'}).YI_{i'}$	$i \in INSDNG$ $i' \in INSDNG'$	(27)

For private consumption of domestic non-government institutions, only households demand commodities. Household consumption expenditure is expressed in equation (28). This is the net income that remains after direct tax payments, savings, and transfers to other domestic non-government institutions. The model assumes that households maximize utility subject to consumption expenditure constraints. The Stone-Geary function is applied for calculating household utility. The first-order condition, equation (29), indicates that household consumption expenditures on a given commodity is a function of total household consumption spending, the market price of that commodity, and other commodity prices. The investment demand for commodities is defined as the base-year quantity of fixed investment demand multiplied by an adjustment factor, as presented in equation (30). The adjustment factor is the proportional change in investment quantity and is treated as exogenous.

Household consumption expenditure	$EH_h = (1 - \sum_{i \in INSDNG} shii_{i\,h}).(1-MPS_h).(1-TINS_h).YI_h$	$h \in H$	(28)
Household consumption demand for marketed commodities	$PQ_c.QH_{c\,h}$ $= PQ_c.\gamma^m_{c\,h}$ $+\beta^m_{c\,h}.\left(EH_h - \sum_{c' \in C} PQ_{c'}.\gamma^m_{c'\,h} - \sum_{a \in A} \sum_{c' \in C} PXAC_{a\,c'}.\gamma^h_{a\,c'\,h} \right)$	$c \in C$ $h \in H$	(29)
Investment demand	$QINV_c = I\overline{ADJ}.\overline{qinv}$	$c \in CINV$	(30)

Total government revenue, equation (31), is the total revenue from taxes, factor inputs, and transfers from the rest of the world. Government tax revenues come from direct taxes from institutions, direct taxes from factors, value-added tax, activity tax, import tariffs, export tax, and sales tax. Like investment demand, fixed government consumption demand, equation (32), is defined as the base-year government consumption multiplied by an exogenous adjustment factor. In equation (33), total government spending is the sum of government spending on consumption and transfers to domestic non-government institutions.

Government revenue

$$YG = \sum_{i \in INSDNG} TINS_i.YI_i + \sum_{f \in F} tf_f.YF_f + \sum_{a \in A} tva_a.PVA_a.QVA_a + \sum_{a \in A} ta_a.PA_a.QA_a + \sum_{c \in CM} tm_c.pwm_c.QM_c EXR + \sum_{c \in CE} te_c.pwe_c.QE_c EXR + \sum_{c \in C} tq_c.PQ_c.QQ_c + \sum_{f \in F} YIF_{gov\,f} + trnsfr_{gov\,row}.EXR \quad (31)$$

Government consumption demand

$$QG_c = \overline{GADJ}.\overline{qg_c} \qquad c \in C \quad (32)$$

Government expenditures

$$EG = \sum_{c \in C} PQ_c.QG_c + \sum_{i \in INSDNG} trnsfr_{i\,gov}.\overline{CPI} \quad (33)$$

System Constraint Block

Before discussing system constraint blocks, the model's closures for macroeconomic balance are revisited. There are three closures that must be taken into account: government balance, saving-investment balance, and external balance. These three closures are expressed in a system constraint block.

The system constraint block includes the macro constraints that satisfy the economy as a whole. In the factor markets, equation (34) expresses the factor market equilibrium condition in which the total quantity of a given factor demanded and the total quantity supplied are equivalent. The supply of factors of production is considered as a fixed value. Wage is the factor market clearing variable. For composite commodity markets, presented in equation (35), the supply and demand of the composite commodity are equal. Composite commodity demand consists of demands from intermediate uses of the composite commodity in production activities, demand from trade input uses, household and government consumption demands, investment demand, and changes in capital stock. The supply of composite commodities consists of domestically produced output sold in the domestic market, and imports. The market-clearing variable is the composite price.

Equation (36) expresses the current account balance in foreign currency. The current account balance, or the external balance, refers to the balance of a country’s spending and earning of foreign exchange. In this research, foreign savings, the difference between foreign currency spending and income, are considered fixed. The exchange rate serves the role of clearing the current account balance.

The government balance, equation (37), shows the balance of government revenue and the sum of its expenditures and savings. The model’s government closure, with flexible government saving and fixed direct tax rates were chosen for this study. Particularly, government saving is an endogenous variable that clears the government balance.

For saving-investment balance, the selected closure is an investment-driven closure, where the value of savings is an adjustment to clear the balance. Equation (38) identifies the direct tax rates applied for domestic non-government institutions. Variables on the right-hand side are supposed to be fixed, in effect fixing the values for the direct tax rate variable for all institutions. Equation (39) describes the savings rates of domestic non-government institutions. The savings rate is supposed to vary and can be adjusted at a uniform rate for designated non-government institutions. The saving-investment balance is shown by equation (40). It reveals that total savings and total investment are equal. Total savings is the sum of savings from institutions, while total investment is the sum of the values of fixed investment and changes in stock capital. Other variables are considered as fixed in order to assure that the balance holds.

Factor markets $$\sum_{a \in A} QF_{f\,a} = \overline{QFS}_{f} \qquad f \in F \qquad (34)$$

Composite commodity markets	$QQ_c = \sum_{a \in A} QINT_{c\,a} + \sum_{h \in H} QINT_{c\,h} + QG_c + QINV_c + qdst_c + OT$	$c \in C$	(35)
Current-Account Balance for the ROW	$\sum_{c \in CM} pwm_c.QM_c + \sum_{f \in F} trnsfr_{row\,f} = \sum_{c \in CE} pwe_c.QE_c + \sum_{i \in INSD} trnsfr_{i\,row} + \overline{FSAV}$		(36)
Government Balance	$YG = EG + GSAV$		(37)
Direct Institutional Tax Rates	$TINS_i = \overline{tins_i}.(1 + \overline{TINSADJ}.tins01_i) + \overline{DTINS}.tins01_i$	$i \in INSDNG$	(38)
Institutional Savings Rate	$MPS_i = \overline{mps_i}.(1 + \overline{MPSADJ}.mps01_i) + DMPS.mps01_i$	$i \in INSDNG$	(39)
Savings-Investment Balance	$\sum_{i \in INSD} MPS_i.(1 - TINS_i).Y_i + GSAV + EXR.\overline{FSAV} = \sum_{c \in C} PQ_c.QINV_c + \sum_{c \in C} PQ_c.qdst_c$		(40)

Equations (41) and (42) express the consumer price index (CPI) and the producer price index (DPI) for domestically marketed output. In this study, the CPI is fixed and treated as the numéraire. A numéraire is necessary because it permits comparison of simulated values. All simulated prices and income changes will be interpreted as changes vis-à-vis the numéraire price index.

Consumer price index	$CPI = \sum_{c \in C} PQ_c.cwts_c$	(41)
Product price index	$DPI = \sum_{c \in C} PDS_c.dwts_c$	(42)

Appendix B: Simulated Changes in Import Prices

Sector	Base	S1	S2	S3	S4	S5	S6
Primary Agriculture							
Crops	1.00	-6.19	0.76	0.75	5.73	-5.53	-1.24
Vegetable and Fruit	1.00	-12.07	0.76	0.75	5.73	-11.45	-7.42
Sugar Cane	1.00	4.63	0.76	0.75	5.73	5.36	10.16
Livestock	1.00	-4.02	0.76	0.75	5.73	-3.35	1.05
Resource-Based							
Forestry	1.00	-9.49	0.76	0.75	5.73	-8.85	-4.70
Fishing	1.00	-11.03	-14.32	0.75	5.73	-10.40	-6.33
Coal	1.00	2.11	0.76	0.75	5.73	2.83	7.51
Oil	1.00	4.55	0.76	0.75	5.73	5.28	10.07
Gas	1.00	3.92	0.76	0.75	5.73	4.65	9.41
Mining	1.00	2.44	-1.35	0.75	5.73	3.16	7.86
Agro-Industry							
Meat Products	1.00	-16.24	-19.34	0.75	5.73	-15.65	-11.81
Food Products	1.00	-5.62	0.76	0.75	5.73	-4.96	-0.63
Dairy Products	1.00	-6.47	0.76	0.75	5.73	-5.81	-1.53
Beverages and Tobacco	1.00	-27.02	0.76	0.75	5.73	-26.50	-23.16
Light Manufacturing							
Textile and Apparel	1.00	-4.75	-8.28	0.75	5.73	-4.08	0.28
Leather Products	1.00	-9.65	0.76	0.75	5.73	-9.02	-4.88
Wood Products	1.00	-5.16	0.76	0.75	5.73	-4.50	-0.15
Paper and Publishing	1.00	-0.96	-4.62	0.75	5.73	-0.26	4.28
Heavy Manufacturing							
Petroleum and Coal	1.00	-3.36	0.76	0.75	5.73	-2.68	1.75
Chemical, Rubber, Plastic	1.00	-3.52	-7.09	0.75	5.73	-2.84	1.58
Non-Metal Product	1.00	-7.69	-11.10	0.75	5.73	-7.04	-2.81
Metal Product	1.00	0.59	-3.14	0.75	5.73	1.29	5.90
Transport Equipment	1.00	-11.49	0.76	0.75	5.73	-10.87	-6.81
Electronic Equipment	1.00	2.78	0.76	0.75	5.73	3.51	8.21
Machinery	1.00	-0.38	0.76	0.75	5.73	0.32	4.89
Manufacturing n.e.c.	1.00	-32.04	0.76	0.75	5.73	-31.56	-28.45
Utilities							
Electricity	1.00	4.63	0.76	0.75	5.73	5.36	10.16
Gas Manufacturing	1.00	4.63	0.76	0.75	5.73	5.36	10.16
Water	1.00	4.63	0.76	0.75	5.73	5.36	10.16
Transportation							
Services	1.00	4.63	0.76	0.75	5.73	5.36	10.16
Construction	1.00	4.63	0.76	0.75	5.73	5.36	10.16
Trade and Financial Service	1.00	4.63	0.76	0.75	5.73	5.36	10.16
Communication	1.00	4.63	0.76	0.75	5.73	5.36	10.16
Recreation	1.00	4.63	0.76	0.75	5.73	5.36	10.16
Public Services	1.00	4.63	0.76	0.75	5.73	5.36	10.16
Dwellings	1.00	4.63	0.76	0.75	5.73	5.36	10.16

Source: CGE Simulation Results

Appendix C: Simulated Changes in Levels of Imports

Sector	Base	S1	S2	S3	S4	S5	S6
Total	15570.21	3.67	1.05	-0.73	-2.97	2.96	0.79
Primary Agriculture							
Crops	181.67	8.47	0.34	-1.36	-10.90	7.17	-2.55
Vegetable and Fruit	39.05	20.70	-0.39	-0.88	-13.48	19.76	5.10
Sugar Cane	1.83	-2.06	0.28	-2.45	-17.32	-4.42	-19.11
Livestock	35.99	3.10	-3.37	-0.03	-7.86	3.12	-4.53
Resource-Based							
Forestry	17.48	14.51	-0.11	-2.28	-16.25	11.86	-4.15
Fishing	15.36	34.31	33.05	-1.91	-23.78	32.15	4.96
Coal	100.71	-1.41	-1.35	-4.09	-35.23	-5.57	-37.08
Oil	1895.37	-1.72	-0.22	-2.92	-17.72	-4.64	-19.27
Gas	221.74	-0.84	-0.29	-3.53	-30.47	-4.33	-30.99
Mining	139.03	-1.75	-0.65	-8.26	-53.40	-10.03	-55.06
Agro-Industry							
Meat Products	17.32	54.91	71.03	0.03	-12.14	54.99	37.06
Food Products	387.90	8.24	-0.83	0.05	-5.29	8.22	2.28
Dairy Products	64.50	11.03	-0.70	-0.65	-9.15	10.42	1.75
Beverages and Tobacco	71.66	88.15	-1.54	-2.77	-23.79	84.15	50.61
Light Manufacturing							
Textile and Apparel	280.16	9.89	13.15	-0.32	-6.59	9.51	2.57
Leather Products	71.12	18.49	-2.38	-2.59	-25.70	15.53	-11.23
Wood Products	94.66	9.11	-0.59	-3.13	-22.72	5.88	-14.44
Paper and Publishing	197.17	2.99	4.80	0.74	2.02	3.77	5.36
Heavy Manufacturing							
Petroleum and Coal	273.71	19.90	-0.32	-1.60	-12.61	18.03	5.14
Chemical, Rubber, Plastic	2055.97	2.62	3.24	-0.37	-3.83	2.26	-1.22
Non-Metal Product	117.47	19.12	22.31	18.28	247.51	39.88	295.75
Metal Product	1749.29	-0.20	1.53	0.79	8.18	0.57	7.76
Transport Equipment	891.32	13.42	-1.01	-1.04	-9.39	12.25	2.91
Electronic Equipment	1925.05	1.97	0.43	0.05	1.34	2.09	3.81
Machinery	2220.31	1.15	0.24	-0.15	-1.04	1.03	0.33
Manufacturing n.e.c.	286.72	54.78	-1.72	-0.79	-11.41	53.87	39.30
Utilities							
Electricity	39.21	-2.04	-0.13	31.94	896.72	29.49	882.67
Gas Manufacturing	8.50	-1.48	-0.27	-18.11	-83.15	-19.12	-83.29
Water	4.16	-5.13	-0.55	-2.17	-2.77	-7.07	-6.71
Transportation	518.97	-3.51	-0.02	4.00	19.82	0.43	16.15
Services							
Construction	75.34	-5.17	-2.88	5.02	39.76	-0.60	30.35
Trade and Financial Service	1357.56	-2.11	-0.03	-4.36	-32.00	-6.24	-32.53
Communication	35.02	-1.59	0.44	-5.78	-35.51	-7.14	-35.68
Recreation	80.63	-5.12	-1.19	-1.35	-12.19	-6.40	-16.58
Public Services	96.63	-1.14	0.22	-8.03	-43.74	-8.91	-43.42
Dwellings	1.62	-5.40	-1.14	-2.90	-36.74	-8.01	-39.40

Source: CGE Simulation Results

Appendix D: Production Cost Structure

Sector		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Crops	4.86	5.91	0.00	2.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	25.29	1.45	2.63	0.01	0.01	0.36
2	Vegetable and Fruit	0.04	1.77	0.00	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.26	2.71	6.53	1.56	0.00	0.00	0.00	0.00
3	Sugar Cane	0.00	0.00	7.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.64	0.00	0.00	0.00	0.00	0.00
4	Livestock	0.00	0.00	0.00	5.83	0.00	0.00	0.00	0.00	0.00	0.00	55.00	8.79	0.16	0.00	0.24	3.81	0.00	0.00
5	Forestry	0.01	0.04	0.00	0.01	2.78	0.00	0.00	0.00	0.00	0.21	0.03	0.15	0.03	0.00	0.01	0.01	10.54	1.12
6	Fishing	0.00	0.00	0.00	2.17	0.00	3.25	0.00	0.00	0.00	0.00	0.00	0.00	6.07	0.00	0.00	0.00	0.00	0.00
7	Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.53	0.01	0.00	0.00	0.06
8	Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.67	0.34	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Mining	0.01	0.00	0.00	0.05	0.00	0.00	0.00	0.07	0.05	0.01	0.02	0.00	0.06	0.00	0.01	0.01	0.01	0.08
11	Meat Products	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	9.65	0.00	0.12	0.00	0.00	4.35	0.00	0.00
12	Food Products	0.00	0.01	0.00	32.50	0.00	11.45	0.00	0.00	0.00	0.00	0.68	13.07	18.35	9.51	0.04	0.05	0.01	0.59
13	Dairy Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.25	0.47	0.04	0.00	0.00	0.00	0.00
14	Beverages and Tobacco	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.66	0.00	0.00	0.00	0.00
15	Textile and Apparel	0.16	0.11	0.00	0.02	0.24	0.42	0.00	0.00	0.00	0.04	0.03	0.00	0.07	0.05	37.63	7.31	0.42	0.12
16	Leather Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	12.76	0.58	0.01
17	Wood Products	0.19	0.29	0.00	0.05	0.14	0.02	0.00	0.00	0.00	0.15	0.04	0.00	0.01	0.01	0.02	0.01	16.04	0.02
18	Paper and Publishing	0.05	0.08	0.00	0.05	0.06	0.01	0.11	0.05	0.01	0.07	0.13	0.62	0.37	1.28	0.40	0.41	0.75	27.05
19	Petroleum and Coal	6.38	7.71	11.04	1.60	4.52	21.05	0.05	0.04	0.08	1.43	0.97	1.44	1.16	2.09	0.59	0.25	0.62	2.10
20	Chemical, Rubber and Plastic	12.39	10.32	4.91	2.66	0.52	2.89	0.02	0.27	0.16	2.45	1.20	2.29	1.45	8.26	8.53	12.38	6.09	10.20
21	Non-Metal Product	0.12	0.02	0.00	0.01	0.19	0.07	0.00	0.00	0.00	0.02	0.00	0.00	0.07	3.17	0.01	0.00	0.37	0.02
22	Metal Product	1.20	2.16	1.38	0.24	4.64	0.03	0.09	0.00	0.00	2.35	0.61	1.31	1.07	5.57	0.19	1.03	2.17	0.56
23	Transport Equipment	0.19	0.89	0.20	0.23	0.90	1.89	0.10	0.28	1.83	9.76	0.21	0.25	0.15	0.60	0.10	0.21	0.32	0.13
24	Electronic Equipment	0.07	0.00	0.00	0.02	0.03	0.00	0.00	0.04	0.06	0.02	0.01	0.29	0.03	0.03	0.06	0.04	0.04	0.11
25	Machinery	0.83	0.93	2.16	0.30	2.84	0.77	2.87	1.78	1.70	2.99	0.19	0.65	0.79	0.98	0.73	0.50	1.20	1.61
26	Manufacturing n.e.c	0.02	0.06	0.01	0.07	0.08	0.02	0.07	0.28	0.35	0.06	0.05	0.03	0.05	0.03	1.83	6.01	0.41	0.14
27	Electricity	0.04	0.03	0.03	0.26	0.05	0.11	0.00	0.00	0.00	0.19	1.23	2.11	2.69	1.09	2.95	0.32	2.62	3.04
28	Gas manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.03	0.01	0.11	0.00	0.02	0.03	0.05	0.35
29	Water	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.19	0.13	0.18	0.15	0.05	0.11	0.27

Sector		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
30	Construction	0.02	0.01	0.00	0.13	0.08	0.12	0.05	0.03	0.05	0.23	0.05	0.04	0.03	0.04	0.06	0.06	0.06	0.11
31	Trade and Financial Service	7.28	9.44	13.32	7.47	4.46	6.04	2.14	18.81	12.91	6.00	9.08	8.06	7.88	11.03	9.14	12.17	16.70	15.08
32	Transportation	1.29	1.35	2.69	0.79	0.84	0.87	16.91	0.50	0.60	5.67	1.01	2.90	1.65	2.13	0.92	1.31	2.36	1.92
33	Communication	0.32	0.41	0.02	0.04	0.07	0.01	0.30	0.09	0.09	0.46	0.10	0.45	0.25	0.26	0.34	0.23	0.29	0.71
34	Recreation	0.08	0.31	0.03	0.31	0.41	0.27	0.04	0.11	0.17	0.06	0.27	0.24	0.40	0.97	0.82	0.38	0.26	0.26
35	Public Services	0.00	0.01	0.80	0.00	0.14	0.00	0.01	0.03	0.03	0.12	0.05	0.02	0.07	0.27	0.10	0.04	0.05	0.26
36	Dwellings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Land	32.50	29.21	28.00	21.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Agricultural Unskilled Labor	26.73	24.03	23.03	17.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Agricultural Skilled Labor	0.03	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-Agricultural Unskilled Labor	0.00	0.00	0.00	0.00	38.01	5.90	11.07	10.17	13.83	14.12	5.36	6.85	5.59	8.74	9.89	11.67	13.13	8.05
	Non-Agricultural Skilled Labor	0.00	0.00	0.00	0.00	0.04	0.01	1.15	2.20	2.25	2.17	0.91	1.09	1.20	1.31	1.51	1.79	1.71	1.61
	Agricultural Capital	4.46	4.01	3.84	2.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-Agricultural Capital	0.00	0.00	0.00	0.00	31.20	21.13	38.67	32.05	38.60	43.78	12.66	22.99	14.87	28.89	20.89	22.77	22.98	23.78
	Natural Resource	0.00	0.00	0.00	0.00	7.24	21.31	26.35	25.44	26.83	7.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Tax	0.72	0.87	1.24	0.18	0.51	2.37	0.00	0.00	0.00	0.18	0.13	0.19	0.17	0.25	0.10	0.03	0.10	0.30
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: Author's calculation based on Thailand Social Accounting Matrix

Appendix D: Production Cost Structure (Cont.)

Sector		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	Crops	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.01	0.12	0.00	0.00	0.42	0.00	0.00
2	Vegetable and Fruit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.11	0.00	1.00	0.67	0.00
3	Sugar Cane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
4	Livestock	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.11	0.05	0.00
5	Forestry	0.00	0.10	0.27	0.02	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.29	0.02	0.00	0.00	0.03	0.00	0.00
6	Fishing	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.03	0.10	0.00
7	Coal	0.00	0.04	5.91	0.04	0.00	0.00	0.01	0.04	5.52	0.00	0.00	0.01	0.00	0.00	0.00	0.05	0.00	0.00
8	Oil	79.16	3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Gas	4.01	0.26	0.00	0.00	0.00	0.00	0.00	0.00	10.99	12.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Mining	0.00	0.47	12.38	6.98	0.20	0.01	0.12	1.50	0.00	0.00	0.06	6.03	0.00	0.00	0.00	0.35	0.00	0.00
11	Meat Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	1.29	0.00	0.00	0.50	0.16	0.00
12	Food Products	0.03	0.78	0.28	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	1.53	0.12	0.00	2.44	0.57	0.00
13	Dairy Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.03	0.00	0.06	0.15	0.00
14	Beverages and Tobacco	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.32	0.00	0.90	0.00	0.00
15	Textile and Apparel	0.00	1.12	0.29	0.06	0.31	0.04	0.27	2.64	0.01	0.00	0.02	0.08	0.49	0.21	0.00	2.07	0.19	0.00
16	Leather Products	0.00	0.01	0.02	0.00	0.04	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.49	0.00	0.00
17	Wood Products	0.00	0.07	0.20	0.35	0.24	0.08	0.25	0.47	0.00	0.01	0.00	2.39	0.09	0.06	0.00	0.27	0.05	0.05
18	Paper and Publishing	0.02	0.37	0.65	0.28	0.41	0.22	0.39	0.70	0.03	0.14	0.09	0.07	1.87	0.21	0.29	1.37	1.87	0.04
19	Petroleum and Coal	6.98	3.91	2.67	1.49	0.02	0.05	0.32	0.37	5.34	0.01	0.01	0.51	0.03	36.16	0.02	0.06	0.04	0.00
20	Chemical, Rubber, Plastic	0.48	37.53	8.91	3.80	7.42	4.32	4.76	6.23	0.11	0.06	3.68	2.64	1.20	1.13	0.08	6.75	5.22	0.03
21	Non-Metal Product	0.00	0.14	8.69	0.20	0.56	0.26	2.41	1.40	0.00	0.00	0.09	21.42	0.07	0.00	0.00	0.95	0.02	0.01
22	Metal Product	0.03	0.46	1.35	42.61	11.72	5.93	12.10	21.08	0.02	0.69	0.18	10.48	0.08	0.11	0.11	2.85	0.15	0.05
23	Transport Equipment	0.03	0.16	0.37	0.14	27.01	0.18	0.31	0.42	0.05	0.11	0.10	0.50	0.26	7.96	0.33	0.51	0.35	0.00
24	Electronic Equipment	0.01	0.04	0.06	0.03	1.65	45.51	0.38	0.25	0.05	0.11	0.19	0.08	0.17	0.12	2.03	5.36	0.16	0.00
25	Machinery	0.10	0.70	1.43	0.91	14.41	2.99	38.80	0.79	0.85	1.97	0.15	7.52	0.46	0.29	0.68	3.04	0.08	0.02
26	Manufacturing n.e.c	0.01	0.21	0.18	0.12	0.39	0.42	0.28	16.52	0.02	0.16	0.93	0.14	0.23	0.10	0.10	3.09	0.78	0.03
27	Electricity	0.00	2.08	6.64	4.00	0.02	1.08	1.57	0.10	3.36	0.00	13.76	0.01	2.47	0.49	2.61	2.75	1.87	0.01
28	Gas Manufacturing	0.07	1.11	0.54	0.41	0.03	0.03	0.08	0.33	48.45	4.08	0.00	0.02	0.03	0.20	0.00	0.06	0.01	0.00
29	Water	0.01	0.12	0.17	0.07	0.05	0.14	0.04	0.09	0.01	0.28	2.07	0.03	0.09	0.05	0.16	0.23	0.04	0.18

Sector		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
30	Construction	0.01	0.07	0.19	0.06	0.07	0.12	0.06	0.06	0.05	0.25	0.04	0.06	0.11	0.02	0.09	0.24	0.08	1.05
31	Trade and Financial Service	0.62	8.76	8.31	6.25	7.88	11.79	7.84	12.12	1.94	12.31	9.53	12.57	9.92	7.78	8.84	10.61	3.85	3.22
32	Transportation	0.11	1.25	2.46	1.08	0.96	1.48	1.19	1.42	0.24	0.68	0.23	9.11	1.69	11.51	2.25	2.96	0.61	0.03
33	Communication	0.13	0.39	0.79	0.37	0.66	0.48	0.45	1.03	0.08	1.02	0.17	0.18	1.82	0.70	17.61	5.02	0.43	0.01
34	Recreation	0.06	0.19	0.53	0.27	0.84	0.32	0.23	0.35	0.32	3.30	0.67	0.24	3.82	0.36	2.19	10.57	0.38	0.34
35	Public Services	0.03	0.16	0.39	0.13	0.12	0.17	0.09	0.12	0.04	1.05	0.74	0.15	0.28	0.17	0.35	0.76	0.34	0.00
36	Dwellings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
	Land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Agricultural Unskilled Labor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Agricultural Skilled Labor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-Agricultural Unskilled Labor	1.81	8.06	8.09	8.37	6.12	5.11	6.08	9.64	4.69	8.88	17.59	8.48	14.98	9.63	10.16	9.08	26.93	0.13
	Non-Agricultural Skilled Labor	0.37	1.93	1.39	1.48	1.26	1.29	1.53	1.28	2.24	4.23	8.39	1.50	4.94	1.96	7.92	7.08	41.42	0.00
	Agricultural Capital	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Non-Agricultural Capital	5.91	24.25	26.01	20.24	17.61	17.97	20.37	19.42	10.19	48.24	41.14	15.40	48.73	16.09	44.15	17.86	13.41	94.78
	Natural Resource	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Tax	0.00	1.02	0.83	0.24	0.00	0.02	0.06	0.07	5.40	0.00	0.15	0.06	0.03	4.09	0.03	0.04	0.03	0.00
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: Author’s calculation based on Thailand Social Accounting Matrix

Appendix E: Simulated Changes in Returns on Labor

	Base	S1	S2	S3	S4	S5	S6
Agricultural Unskilled Labor	1.00	0.10	1.42	-1.39	-11.82	-1.22	-11.40
Agricultural Skilled Labor	1.00	1.11	0.82	-2.05	-16.50	-0.89	-15.33
Non-Agricultural Unskilled Labor	1.00	5.18	1.59	-6.36	-36.10	-1.34	-31.77
Non-Agricultural Skilled Labor	1.00	5.28	1.52	-5.74	-34.22	-0.61	-29.78

Source: CGE Simulation Results

Appendix F: Simulated Changes in Returns on Land

	Base	S1	S2	S3	S4	S5	S6
Crops	1.00	-0.83	3.13	-1.47	-7.82	-2.16	-8.17
Vegetable and Fruit	1.00	1.56	2.06	-0.80	-10.64	0.80	-8.93
Sugar Cane	1.00	9.76	3.47	-4.96	-32.09	4.50	-25.18
Livestock	1.00	-3.21	-5.01	-2.02	-20.34	-5.14	-22.68

Source: CGE Simulation Results

Appendix G: Simulated Changes in Returns on Natural Resources

	Base	S1	S2	S3	S4	S5	S6
Forestry	1.00	-15.39	1.91	2.08	9.23	-13.45	-7.02
Fishing	1.00	0.33	-8.39	-7.25	-45.82	-6.73	-44.20
Coal	1.00	3.91	0.66	-8.54	-60.83	-4.97	-59.49
Oil	1.00	4.84	0.69	-2.27	-8.89	2.36	-5.24
Gas	1.00	5.56	0.87	-3.19	-24.12	2.19	-19.93
Mining	1.00	3.96	-2.95	-10.32	-60.78	-6.70	-58.92

Source: CGE Simulation Results

Appendix H: Simulated Changes in Returns on Agricultural Capital

	Base	S1	S2	S3	S4	S5	S6
Crops	1.00	-0.83	3.13	-1.47	-7.82	-2.16	-8.17
Vegetable and Fruit	1.00	1.56	2.06	-0.80	-10.64	0.80	-8.93
Sugar Cane	1.00	9.76	3.47	-4.96	-32.09	4.50	-25.18
Livestock	1.00	-3.21	-5.01	-2.02	-20.34	-5.14	-22.68

Source: CGE Simulation Results

Appendix I: Simulated Changes in Returns on non-Agricultural Capital

	Base	S1	S2	S3	S4	S5	S6
Resource-Based							
Forestry	1.00	-15.39	1.91	2.08	9.23	-13.45	-7.02
Fishing	1.00	0.33	-8.39	-7.25	-45.82	-6.73	-44.20
Coal	1.00	3.91	0.66	-8.54	-60.83	-4.97	-59.49
Oil	1.00	4.84	0.69	-2.27	-8.89	2.36	-5.24
Gas	1.00	5.56	0.87	-3.19	-24.12	2.19	-19.93
Mining	1.00	3.96	-2.95	-10.32	-60.78	-6.70	-58.92
Agro-Industry							
Meat Products	1.00	3.25	-3.34	-5.98	-35.94	-2.78	-32.84
Food Products	1.00	10.73	2.73	-7.27	-39.89	2.98	-32.12
Dairy Products	1.00	-3.77	2.33	-7.01	-42.29	-10.51	-44.50
Beverages and Tobacco	1.00	-16.66	2.36	-4.92	-35.80	-20.66	-45.98
Light Manufacturing							
Textile and Apparel	1.00	5.63	-0.75	-7.12	-42.57	-1.64	-38.16
Leather Products	1.00	4.51	4.26	-4.22	-25.15	0.51	-19.11
Wood Products	1.00	4.40	2.51	-3.05	-20.55	1.48	-15.50
Paper and Publishing	1.00	2.83	-2.56	-7.01	-40.59	-4.32	-38.70
Heavy Manufacturing							
Petroleum and Coal	1.00	0.64	1.05	-12.82	-60.80	-12.28	-60.35
Chemical, Rubber, Plastic	1.00	6.55	0.97	-7.23	-38.94	-0.85	-33.47
Non-Metal Product	1.00	-1.52	-5.93	-19.55	-89.27	-21.68	-91.38
Metal Product	1.00	6.13	1.46	-19.40	-86.05	-14.10	-84.44
Transport Equipment	1.00	1.06	4.67	-6.57	-34.16	-5.29	-31.66
Electronic Equipment	1.00	13.48	3.48	-5.87	-29.89	7.29	-17.97
Machinery	1.00	10.47	4.66	-3.44	-23.61	7.06	-13.01
Manufacturing n.e.c.	1.00	-17.75	5.43	-5.83	-32.66	-22.71	-44.92
Utilities							
Electricity	1.00	5.30	1.12	-10.82	-66.60	-5.89	-64.06
Gas Manufacturing	1.00	5.23	0.80	-12.86	-76.09	-8.08	-74.21
Water	1.00	5.09	1.43	-6.67	-42.21	-1.75	-38.35
Transportation	1.00	8.22	1.31	-11.76	-56.45	-4.32	-51.99
Services							
Construction	1.00	5.65	1.83	-6.68	-37.87	-1.23	-33.25
Trade Financial Service	1.00	4.74	1.14	-3.23	-25.15	1.45	-20.94
Communication	1.00	4.63	1.25	-4.19	-29.80	0.35	-25.85
Recreation	1.00	6.20	1.76	-5.58	-36.80	0.45	-31.87
Public Services	1.00	5.12	1.48	-5.45	-33.09	-0.47	-28.72
Dwellings	1.00	1.93	0.26	-1.37	-22.38	0.59	-20.50

Source: CGE Simulation Results

Appendix J: Household's Consumption Pattern Classified by Quintile Groups

	Q1	Q2	Q3	Q4	Q5
Crop	10.18	6.56	4.40	2.76	1.28
Vegetable and Fruit	6.03	5.27	4.53	3.61	2.33
Sugar	2.32	1.91	1.49	1.10	0.59
Food Products	18.11	17.85	17.53	16.04	11.22
Meat Products	6.10	5.06	3.95	2.74	1.42
Dairy Products	4.23	3.46	2.83	2.13	1.18
Beverage	2.59	3.12	3.19	2.90	2.41
Tabaco	0.81	0.85	0.86	0.71	0.37
Textile	2.54	3.00	3.15	3.21	3.64
Petroleum	6.09	5.18	4.32	3.85	3.81
Chemical	1.71	1.55	1.38	1.16	0.76
Transport Equipment	2.53	4.06	5.58	8.78	14.59
Electronic Equipment	0.36	0.42	0.47	0.48	0.64
Electricity	3.17	3.14	3.10	2.93	2.29
Gas	1.09	1.98	2.87	3.43	3.22
Water	1.08	1.05	1.03	0.90	0.59
Transportation	0.93	1.39	1.59	1.65	0.99
Service	1.65	1.96	2.22	2.57	3.73
Communication	2.56	3.34	3.71	3.94	3.49
Recreation	2.03	3.11	4.11	5.05	6.54
Public Service	1.58	1.86	2.13	2.23	1.84
Housing	13.48	13.61	13.63	13.10	12.44
Household Manufacturing	2.92	2.74	2.64	2.49	2.20
Non-Consumption	5.92	7.53	9.30	12.24	18.43

Source: Author's calculation from Household Socio-Economics Survey (2005)

Appendix K: Sources of Household's Revenue Classified by Quintile Groups

Sources of Income	Q1	Q2	Q3	Q4	Q5
Agricultural Unskilled Labor	6.01	5.41	2.96	0.92	0.13
Agricultural Skilled Labor	0.60	1.20	1.26	0.79	0.12
Unskilled Labor	14.24	17.17	14.27	11.38	1.56
Skilled Labor	6.56	13.63	23.92	35.91	51.91
Income from Industry	11.08	21.25	28.84	29.12	26.32
Income from Agriculture	22.33	16.81	11.37	7.00	5.27
Income from Natural resource	0.15	0.83	0.67	0.43	0.49
Income from other Sources	39.19	23.70	16.71	14.45	14.22
Total	100.00	100.00	100.00	100.00	100.00

Source: Author's calculation from Household Socio-Economics Survey (2005)

Appendix L: Share of Household Revenue from Industries Related Sectors Classified by Quintile Groups

Sector	Q1	Q2	Q3	Q4	Q5
Food and Beverage Products	5.76	3.46	3.01	2.06	3.33
Textiles	5.94	3.82	2.71	1.99	1.42
Leather Products	0.27	0.14	0.15	0.24	0.13
Wood Products and Furniture	6.34	2.51	1.45	0.79	1.38
Paper and Publishing	0.03	0.15	0.26	0.24	0.38
Rubber and Plastic Products	0.04	0.11	0.25	0.04	0.24
Transport Equipment	1.46	1.18	1.38	2.05	1.63
Other Manufacturing	1.93	1.65	1.25	1.21	1.07
Utilities	0.00	0.09	0.18	0.10	0.09
Construction	18.29	8.27	4.35	4.19	5.51
Trade and Financial Services	31.52	40.51	48.26	50.04	55.75
Recreation	16.84	18.81	20.57	19.27	10.47
Transportation	11.48	8.90	7.60	7.50	4.43
Other Services	0.10	10.41	8.60	10.28	14.16
Grand Total	100.00	100.00	100.00	100.00	100.00

Source: Author's calculation from Household Socio-Economics Survey (2005)

Appendix M: Share of Household Revenue from Agricultures Related Sectors Classified by Quintile Groups

Sector	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Crops and Vegetable	75.24	65.96	57.60	53.17	29.92
Fruit	8.43	17.48	30.74	38.26	45.40
Livestock	3.79	5.82	6.09	6.71	22.84
Agricultural Services	12.54	10.66	5.57	1.86	1.85
Grand Total	100.00	100.00	100.00	100.00	100.00

Source: Author's calculation from Household Socio-Economics Survey (2005)

Appendix N: Share of Household Revenue from Natural Resources Related Sectors Classified by Quintile Groups

Sector	Q1	Q2	Q3	Q4	Q5
Forestry	14.18	13.76	6.17	3.89	2.14
Fishery	85.82	86.24	93.83	96.11	97.86
Grand Total	100.00	100.00	100.00	100.00	100.00

Source: Author's calculation from 2005 Household Socio-Economics Survey

Appendix O: Changes in Composite Prices

Sector	Base	S1	S2	S3	S4	S5	S6
Primary Agriculture							
Crops	1.002	-1.78	0.84	0.04	-0.63	-1.69	-2.34
Vegetable and Fruit	1.002	-0.67	0.49	0.19	-2.96	-0.46	-3.59
Sugar Cane	1.016	2.58	0.80	-0.61	-4.82	1.92	-2.90
Livestock	1.003	-1.90	-0.92	0.77	1.21	-1.15	-0.79
Resource-based							
Forestry	1.014	-4.36	0.71	-0.32	-2.06	-4.72	-6.74
Fishing	1.004	-0.20	-4.18	0.03	-4.38	-0.10	-4.01
Coal	1.000	1.93	0.57	0.19	-0.46	2.05	0.79
Oil	1.000	4.41	0.74	0.51	3.99	4.89	8.10
Gas	1.000	3.76	0.71	0.09	-1.33	3.81	1.97
Mining	1.003	2.02	-1.41	-1.53	-14.16	0.38	-13.25
Agro-industry							
Meat Products	1.004	-2.14	-2.38	0.72	1.43	-1.47	-0.87
Food Products	1.005	-3.24	0.46	0.85	4.95	-2.48	1.05
Dairy Products	1.019	-3.12	0.52	0.65	4.13	-2.49	0.84
Beverages and Tobacco	1.446	-9.47	0.21	-0.25	-2.76	-9.49	-10.55
Light Manufacturing							
Textile and Apparel	1.005	-1.63	-4.22	0.77	5.18	-0.93	2.97
Leather Products	1.013	-4.45	-0.20	-0.21	-4.17	-4.67	-8.55
Wood Products	1.008	-2.24	0.50	-0.44	-3.39	-2.65	-5.46
Paper and Publishing	1.005	0.20	-2.95	1.00	6.98	1.16	6.90
Heavy Manufacturing							
Petroleum and Coal	1.049	2.89	0.71	1.02	6.69	3.92	9.46
Chemical, Rubber, Plastic	1.003	-2.71	-6.14	0.75	5.41	-2.03	2.11
Non-Metal Product	1.004	-1.68	-4.52	7.25	68.47	5.13	62.34
Metal Product	1.001	0.68	-2.80	1.59	13.21	2.22	13.33
Transport Equipment	1.029	-7.56	0.28	0.54	3.20	-7.10	-4.96
Electronic Equipment	1.004	2.83	0.74	0.74	5.59	3.55	8.12
Machinery	1.012	-0.16	0.65	0.59	4.74	0.39	4.10
Manufacturing n.e.c.	1.014	-21.58	0.01	0.53	2.45	-21.12	-19.22
Utilities							
Electricity	1.005	3.87	0.79	11.81	149.95	16.16	159.02
Gas Manufacturing	1.002	4.08	0.74	-5.43	-38.51	-1.54	-36.17
Water	1.036	2.78	0.59	0.09	6.73	2.88	9.66
Transportation	1.002	2.61	0.81	3.65	22.90	6.35	25.84
Services							
Construction	1.008	1.75	-0.78	3.39	26.21	5.05	26.77
Trade and Financial Service	1.020	3.73	0.81	-1.68	-12.86	2.02	-9.36
Communication	1.004	3.91	1.03	-2.51	-16.02	1.35	-12.44
Recreation	1.041	1.82	0.14	-0.05	0.14	1.73	1.59
Public Services	0.993	4.09	0.90	-3.70	-22.02	0.30	-18.42
Dwellings	1.150	1.64	0.16	-0.82	-16.86	0.85	-15.29

Source: CGE Simulation Results

Appendix P: Effects of Carbon Tax on Household's Incomes (Average) in Percentage Changes

	Carbon Tax (Baht/tCO_2e)					
	100	**500**	**1000**	**1500**	**2000**	**2500**
Q1	5.41	3.60	0.74	-2.38	-6.29	-11.25
Q2	6.76	4.31	0.38	-3.81	-8.94	-15.10
Q3	8.38	5.40	0.52	-4.61	-10.81	-17.95
Q4	11.46	7.95	2.33	-3.56	-10.59	-18.68
Q5	14.84	18.73	8.87	2.57	-4.86	-13.53

Source: Author's calculation